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ENVIRONMENTAL

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Union Pacific Railroad Company
Eunice Train Derailment
Agency Interest Number 85276

Date:
7 August 2006

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Our ref:
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Dear Mr. Casanova:

ARCADIS, on behalf of its client Union Pacific Railroad Company (UPRR), is pleased to provide three copies of the above referenced report. The major change from the previous edition is the addition of a third bridge configuration to Alternative 6. The additional configuration will provide for longer bridge spans, greater openings for the drainage area of the tributary and a greater volume of soil removed from the railroad embankment.

If there are any questions concerning this submittal, please contact one of the undersigned or Mr. Geoffrey Reeder at (281) 350-7197.

Sincerely,

ARCADIS G&M, Inc.

George H. Cramer, II, P.G.
Associate Vice President/Principal Hydrogeologist

Rudy J. Guichard
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GHC:RJG:cdb

Attachments

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UNION PACIFIC RAILROAD COMPANY

REVISED CORRECTIVE ACTION STUDY

EUNICE TRAIN DERAILMENT
MAY 27, 2000
AGENCY INTEREST NO. 85276

ARCADIS
Infrastructure, environment, facilities

ARCADIS

Revised Corrective Action Study

Eunice Train Derailment
May 27, 2000
Agency Interest No. 85276

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Prepared for:
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Date:
4 August 2006

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Executive Summary

This Corrective Action Study (CAS) was prepared on behalf of Union Pacific Railroad Company for the Eunice Train Derailment at the request of the Louisiana Department of Environmental Quality (LDEQ) in a letter dated March 23, 2005. In this letter, LDEQ indicated that ARCADIS had adequately delineated the vertical and horizontal extent of constituents in soil and that groundwater has not been impacted above Risk Evaluation/Corrective Action Program (RECAP) standards. LDEQ further requested the evaluation of remedial alternatives for soil to achieve rapid and successful remediation to appropriate standards. This CAS was prepared in accordance with Louisiana Administrative Code (LAC) 33:VI.509 and the U.S. Environmental Protection Agency *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (1988).

Numerous soil investigations have been conducted in the railbed area of the derailment (i.e., the study area). As a result of these investigations, the extent of the soil impacts has been adequately defined and an area of investigation (AOI) has been identified in accordance with RECAP. The constituents of concern (COC) for the AOI include the following compounds: 1,2-dichloropropane, chloromethane, hexane, acrylic acid, dicyclopentadiene, naphthalene, phenol, and toluene diisocyanate. The technologies evaluated to remediate these COC included no action, in situ containment (stabilization and capping), in situ treatment (chemical, biological, and thermal), and removal and treatment/disposal. The CAS evaluated these technologies against three screening criteria: effectiveness, implementability, and relative cost.

Based upon the analysis of the remedial alternatives, the best balance between all the factors considered is to utilize Alternative 6C, Embankment Excavation and Enhanced Reductive Dechlorination. This alternative provides for a longer replacement bridge than was originally at the Site, allowing the removal of the railroad embankment over the most impacted areas within the AOI. It provides for in situ treatment of the below ground impacts and ex situ treatment of the impacted materials removed from the embankment area. This alternative provides the following attributes: permanent destruction of COC in all impacted soils, improvement of the pre-derailment drainage within the tributary, minimal impact on critical rail service, low impact on surrounding community, readily implementable, and moderate capital and low O&M costs.

F I N A L

1.0 Introduction

This Corrective Action Study (CAS) was prepared on behalf of Union Pacific Railroad Company (Union Pacific) for the Eunice Train Derailment (herein called the Site) at the request of the Louisiana Department of Environmental Quality (LDEQ) in their letter of March 23, 2005. In this letter, LDEQ indicated that ARCADIS had adequately delineated the vertical and horizontal extent of constituents in soil and that groundwater has not been impacted above Risk Evaluation/Corrective Action Program (RECAP) standards. LDEQ further requested a CAS to evaluate remedial alternatives for soil to achieve rapid and successful remediation to appropriate standards.

This CAS summarizes the Site history and remedial investigation (RI), including ecological and human health risk assessments (HHRA), identifies and screens potentially applicable technologies and process options, and ultimately develops and presents a detailed evaluation of applicable remedial alternatives. This CAS was prepared in accordance with Louisiana Administrative Code (LAC) 33:VI.509 and the U.S. Environmental Protection Agency (USEPA; 1988) *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*.

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1.1 Objectives

The purpose of the CAS is to develop and evaluate remedial alternatives capable of addressing the environmental impacts in and around the derailment site. The CAS develops Remedial Action Objectives (RAOs) and RECAP Standards (RS) to be used as Remediation Goals (RGs). It also identifies general response actions and applicable technology groups potentially capable of meeting the RAOs and RGs. Technology process options are then identified and screened for effectiveness, implementability, and relative cost. The most applicable process options are then assembled into remedial alternatives and a detailed comparative analysis is performed. The ultimate objective of the CAS is to develop and evaluate remedial alternatives in sufficient detail so as to enable final remedy selection for the Site soils.

1.2 Organization of the Corrective Action Study

The subsequent sections are as follows:

- Site Background (Section 2.0) - Describes the Eunice derailment site, summarizes historic information and site characteristics, describes remedial activities, and also provides information regarding the local environment;

- Nature and Extent of Contamination (Section 3.0) - Presents a summary of historic sampling data and defines the nature and extent of contamination at the Site. It also provides a conceptual model of contaminant transport;

- Human Health Risk Assessment Summary (Section 4.0) - Summarizes the characterization and evaluation of the current and potential threats to public health posed by the constituents of concern (COC);

- Screening Level Ecological Risk Assessment (Section 5.0) - Summarizes the characterization and evaluation of the current and potential threats to the environment posed by the constituents detected at the Site;

- Remedial Action Objectives (Section 6.0) - Summarizes the potential regulatory requirements that may be applicable to the Site and identifies RAOs and COC and develops RGs;

- Identification and Screening of Remedial Technologies (Section 7.0) - Presents the general response actions potentially applicable to site conditions and screens treatment technologies and technology process options for soil at the Site;

- Identification and Detailed Analysis of Remedial Alternatives (Section 8.0) - Describes the development of remedial alternatives from combinations of the screened technologies and process options; evaluates the remedial alternates with respect to threshold, balancing, and modifying criteria; and presents a comparative analysis of remedial alternatives to identify the relative strengths, weaknesses, and trade-offs among alternatives;

- Selection of Remedy (Section 9.0) - Identifies the recommended remedial alternative;

- Contingency Plan (Section 10.0) - Provides contingent actions should the selected remedy not achieve the remedial standards in an acceptable time frame; and

- References (Section 11.0) - Lists the complete reference citation for documents cited in this report.

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2.0 Site Background

2.1 Site Description

The Site is located on the northern side of U.S. Highway 190 in Eunice, Louisiana (Latitude 30°30'10", Longitude 92°27'35"). The Site is in the western portion of St. Landry Parish, Louisiana, in Township 6 South, Range 1 West, Section 27 (Figure 1). The Site is located within a mixed rural/agricultural setting on the western side of the Town of Eunice. The Site is bounded by an unnamed tributary to Bayou des Cannes and woods to the north and a golf course, small lake, and pasture to the south.

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2.2 Site History

2.2.1 Release and Removal Action History

On Saturday, May 27, 2000, 34 cars of the 113-car Union Pacific train derailed at a site northwest of the Town of Eunice, Louisiana. The train cars contained a variety of chemicals including, but not limited to, acrylic acid, toluene diisocyanate, phenol, hexane, pentane, caprolactam, 1,2-dichloropropane, glycol, chloromethane, dicyclopentadiene, disodium iminodiacetate, and alumina. The location of the derailment is a track bridge that crosses an unnamed tributary to Bayou Des Cannes.

The Emergency Response Phase of activities at the Site began with the actual derailment on May 27, 2000, and lasted through June 10, 2000. The Corrective Action Phase, which began in June 2000 and lasted until February 2001, included removal and disposal of impacted materials and construction of containment structures. The corrective actions were performed to contain and/or remove residual chemicals released from the railcars to the surrounding environment. Impacted materials included burned or impacted trees, metal railcar pieces, impacted water from the tributary, and impacted soil primarily within the right of way. Containment structures included dams in the tributary and a temporary French drain on the north side of the track to collect runoff from the area of the track impacted with chemicals carried in the railcars. In addition, six shallow monitor wells and one intermediate monitor well were installed around the impacted area. Later, a monitor well was installed into the Chicot aquifer. The following is a list of the types and approximate amounts of materials removed from the Site:

- 74,937 tons of soil and debris;
- 22,247 tons of wood chips; and
- 1,646,554 gallons of water.

2.2.2 Investigation History

Site investigation sampling was conducted in staged events beginning July 31, 2000, after completion of interim remedial measures in the area of the derailment. The report entitled *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b) summarizes the investigations conducted in the railbed area from June 2000 to June 2002. The report entitled *Additional RECAP Environmental Site Investigation* (ARCADIS 2004) summarizes the August 2004 soil sampling in the derailment area that was conducted to complete the horizontal and vertical delineation of the soil impacts in the area of the railbed.

The table below presents the number of samples collected for each medium during the site investigations (including areas outside of the immediate derailment area):

Medium	Number of Samples Collected
Soil	1,518
Groundwater	62
Sediment	87
Surface Water	243
Fish Tissue	58
Vegetation	46

Detailed discussions of the railbed investigations completed at the Site can be found in the reports entitled *Site Investigation Report of the Railbed Area* (ARCADIS 2002a), *Supplemental Railbed Site Investigation Report* - June 2002 (ARCADIS 2002c), *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b), and *Additional RECAP Environmental Site Investigation* (ARCADIS 2004).

2.2.3 Technology Evaluations

Several efforts to use peroxide oxidation at the Site showed some promise but did not show complete destruction of all target compounds. These efforts included injection of

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the chemical by means of high-pressure lances and piezometers. Each delivery method was observed to have complications that did not allow delivery of sufficient fluid throughout the impacted zone.

In May 2005, ARCADIS performed a technology evaluation on both the north and south sides of the railroad track at the Site to evaluate two different technologies. ERD and chemical oxidation (hydroxyl ion oxidation) were both evaluated at the site to degrade the target compounds. Chemical oxidation was used in the area north of the track, which is impacted with all three primary COC: phenol, dicyclopentadiene, and 1,2-dichloropropane. Two of the three compounds are amenable to chemical oxidation, providing adequate delivery and distribution of the oxidizing agent can be achieved in the low permeability soil. ERD was evaluated in the area south of the track, which is primarily impacted with 1,2-dichloropropane.

Because both chemical oxidation and ERD technologies are dependent on the ability to deliver the reagents to the impacted area and low permeability soils like those at the site present the most challenging environment for delivery of remediation agents, an effective delivery system had to be designed. For this project, a trench delivery system was used.

The application of chemical oxidation was effective on the north side of the tracks on all the COC except 1,2-dichloropropane. The application of enhanced reductive dechlorination (ERD) on the south side of the track was inconclusive due to the inability to collect samples in the same location to evaluate before and after concentrations.

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2.3 Site Characteristics

2.3.1 Land Use

Currently, the railbed area of the Site is utilized for industrial use and this use category is unlikely to change in the future. The railbed falls under the category of Rail Transportation (48211) in the North American Industrial Classification System Codes and Titles. The area outside of the railroad right of way is utilized for non-industrial use.

2.3.2 Regional Geology

The Site is located in the western portion of St. Landry Parish, Louisiana, in Township 6 South, Range 1 West, Section 27. The physiographic region is known as the West Gulf Coastal Plain and the Site is located in the prairie belt (Jones *et al.* 1954). Gentle topographic relief, ranging from 10 to 20 feet, is characteristic of the prairie belt. A gentle southerly (gulfward) dip of approximately 1.5 to 2 feet per mile is typical of the area. Land surface elevations at the Site are typically 30 to 36 feet National Geodetic Vertical Datum (NGVD).

Tertiary and Quaternary geologic deposits characterize the shallow stratigraphy of the area. The Pleistocene Prairie Terrace formation is encountered from ground surface to approximately 100 feet below land surface (ft bls). There are two groundwater bearing formations that are typically encountered in the shallow stratigraphic section in the Eunice area: the Pleistocene Chicot aquifer and the Pliocene/Miocene Evangeline aquifer. A third aquifer, the Miocene Jasper aquifer, is not a principal aquifer system in the Eunice area. A copy of a generalized stratigraphic section is provided in Appendix A. The maximum depth of fresh water, water with a chloride content less than 250 milligrams per liter (mg/L), in the Eunice area occurs at approximately 800 to 1,200 feet NGVD in the Evangeline aquifer (Jones *et al.* 1954-Plate 35).

The Evangeline aquifer system is encountered at a depth of approximately 500 feet NGVD in the Eunice area (Jones *et al.* 1954, Whitfield 1975) (Appendix A). The aquifer material is primarily unconsolidated fine- to medium-grained sand interbedded with silt, soft to moderately hard greenish gray laminated clay and an occasional interval of coarse sand. This sequence of sediments is the result of deltaic deposition (Whitfield 1975). The total thickness of the Evangeline aquifer is approximately 2,500 feet in the Eunice area.

The Chicot aquifer system overlies the Evangeline aquifer and includes the Williana, Bentley, Montgomery, and Prairie Terrace formations (Jones *et al.* 1954). The Chicot aquifer system is the principal source of groundwater in southwestern Louisiana. The sediments of the Chicot system are clays, silts, sands, and gravels. The water bearing zones are primarily massive sands and gravels, grading from fine sand at the top to coarse sands and gravels at the base. The thickness of the beds ranges from several feet to over 800 feet. Water bearing intervals of the Chicot aquifer are separated by clay intervals not more than 50 feet thick.

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The top of the Chicot is encountered at approximately 100 ft bls in the Eunice area (Jones *et al.* 1954-Plate 4; Appendix A). The sand and gravel intervals of the Chicot aquifer system are laterally continuous throughout southwestern Louisiana. The permeability of the aquifer ranges from 900 to 2,000 gallons per day per square foot (gpd/sq ft). Recharge to the Chicot aquifer occurs through infiltration in areas where the formation outcrops and through influent seepage from streams and rivers. Water in the Chicot aquifer is typically calcium magnesium to calcium sodium bicarbonate type, hard to very hard, slightly acid, and generally has a high iron content (Whitfield 1975). Localized areas of heavy pumping have caused increases in chloride content in the aquifer as saltwater is pulled from deeper in the formation.

Sediments of the Prairie Terrace formation are flood plain and deltaic plain deposits formed in an entrenched valley. The formation is approximately 100 feet thick in the Eunice area. Sediments of the Prairie Terrace formation range from clays, silty clays, and silts with calcareous, limonitic, and manganese nodules in the upper portion of the package to silt, sand, and gravel at the base (Varvaro 1957). No significant water bearing zones are encountered in this formation.

2.3.3 Site-Specific Hydrogeology

2.3.3.1 Geologic Setting

The upper 100 feet of sediments at the Site are characterized by slightly rolling, poorly drained, Pleistocene age Prairie Terrace formation clayey soils. Three soil types, the Acadian series (AdB), the Basile series (BL), and the Wrightsville series, characterize the land surrounding the immediate derailment area (Figure 2). The Prairie Terrace formation is the parent material for these soil types. The descriptions of the soils as provided in the *Soil Survey of St. Landry Parish, Louisiana* (U.S. Department of Agriculture 1986) are summarized below. Acadian series soils are located in the wooded areas north and south of the track. These soils are fine-grained, montmorillonitic, clayey alluvium with slopes ranging from 1 to 3 percent. The Basile series soils are located adjacent to the unnamed tributary that crosses under the track. These soils are low permeability, loamy alluvium located in the flood plains on the terrace uplands.

The Wrightsville series soils are found in the open field south of the track that was used for staging excavated soils and equipment. These soils are very low permeability, fine-grained, clayey alluvium and are located on broad flats and in depressional areas on the terrace uplands. A review of the *Recharge Potential of Louisiana Aquifers*

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Map #12 (Lake Charles Quadrangle) of the Aquifer Recharge Atlas (Louisiana Geological Survey 1989) reveals that the surface soils at the Site are Prairie Terrace deposits with low recharge potential (Figure 3).

During the initial site assessment activities, a Cone Penetrometer Testing (CPT) investigation was implemented to define the subsurface geology at the Site. Based on the information gathered during the CPT investigation, the subsurface geology of the Site is characterized by clay and silty clay sediments to a depth of approximately 12 ft bls. A clayey silt zone is encountered at depths ranging from 12 to 20 ft bls. This very thin, clayey silt zone, between 2 and 3 feet thick, is present across the Site. The lateral continuity of this interval is suspect given the thin nature of the zone. Underlying these sediments is a thick zone of clay to silty clay sediments. These sediments are encountered to a depth of approximately 80 to 90 ft bls. A second siltier zone is occasionally encountered under the massive clay to silty clay interval.

During the installation of the Site monitor wells, the shallow stratigraphy defined by the CPT investigation was confirmed. The first water bearing zone, consisting of silty sand, sandy silts, and clayey silts, was screened by the monitor wells installed in that zone (MW-1, MW-2, MW-4, MW-4R, MW-5, and MW-7). The thickness of the zone ranged from 2 feet (MW-2 and MW-4R) to 6 feet (MW-4). The zone was encountered at depths ranging from 9 ft bls (MW-7) to 17 ft bls (MW-1), with an average depth of 9.5 ft bls. Monitor Well MW-6 was screened across approximately 4 feet of clayey sand at a depth of 71 ft bls that was considered the second water bearing zone at the Site. A monitor well in the Chicot Aquifer and two vertical delineation borings (DB-1 and DB-2) were installed in August 2004. These logs are presented in Appendix A. Geologic cross sections constructed from Site data are provided as Figures 4 and 5.

2.3.3.2 *Hydrogeology*

Groundwater is encountered in the first water bearing zone at depths ranging from 1.1 ft bls (MW-5) to 12 ft bls (MW-1) and averaged 5 ft bls. Static water-level measurements were recorded in the monitor wells on February 21, 2001, August 27, 2001, February 13, 2002, August 5, 2002, March 13, 2003, August 20, 2003, February 19, 2004, August 9, 2004, and April 18, 2005. The water level measurements were converted to elevations relative to NGVD to allow for construction of the potentiometric surface maps. Summary tables and potentiometric maps are provided in Appendix A.

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Shallow groundwater movement is interpreted to be consistently toward the tributary, and away from the track area and the Eunice City Lake. The direction of groundwater flow in the second water bearing zone could not be determined because there is only one monitor well screened in this zone.

The rate at which groundwater moves through the first water bearing zone beneath the Site was calculated using Darcy's Law. Darcy's Law can be expressed as the following equation:

$$v = \frac{Ki}{\eta}$$

where:	v	=	groundwater velocity (foot per day [ft/day])
	K	=	hydraulic conductivity (ft/day)
	i	=	hydraulic gradient (foot per foot [ft/ft])
	η	=	effective porosity (decimal percent)

The average hydraulic conductivity of the first water bearing zone, as determined by slug tests conducted on Monitor Wells MW-1, MW-2, MW-5, and MW-7, was calculated to be 0.726 ft/day. The effective porosity of the first water bearing zone is conservatively estimated to be 30 percent.

The hydraulic gradient used in the calculations was determined from the potentiometric surface maps prepared for the first water bearing zone for all nine sampling events. The average hydraulic gradient of the first water bearing zone ranged from 0.1 ft/ft to 0.05 ft/ft, and averaged 0.075 ft/ft. The average horizontal rate of groundwater movement through the first water bearing zone beneath the Site was calculated to be 66.2 feet per year (ft/yr).

2.4 Groundwater Use

In order to classify the first water bearing zone at the Site, calculations of the maximum sustainable well yield were made. An idealized well function equation based on the Cooper and Jacob (1946) approximation to the Theis (1935) solution for radial groundwater flow to a pumping well was used for calculating the sustainable yield. Site-

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specific values for the saturated thickness (b), hydraulic conductivity (K), and confining head (h_c) of the water bearing unit were used. Confined conditions exist for the first water bearing zone at the Site. The RECAP (LDEQ 2003) Appendix F equation was used to calculate the potential sustainable yield from the first water bearing zone. The LDEQ equation for a confined aquifer is:

$$Q = \frac{60 h_c K b}{9.3 + \log(Kb)}$$

where:

Q = sustainable well yield (in gallons per minute [gpm])

K = hydraulic conductivity (in centimeters per second [cm/sec])

b = saturated thickness of the water bearing zone (in feet)

h_c = confining head (in feet)

This equation is conservative in that it provides a steady-state yield rate for a 100 percent efficient water well with water level drawdown during pumping assumed to be 100 percent of the confining head of a confined unit.

The equation for confined conditions was solved with site-specific parameters. A confining head (hc) of 4.5 feet was assumed based on the average depth to water of 5 ft bls and the average depth of the first water bearing zone of 9.5 ft bls. A saturated thickness (b) of 6 feet was used. This thickness is the maximum thickness of saturated sediments, which was observed in Monitor Well MW-4. A hydraulic conductivity (K) of 2.56×10^{-4} cm/sec (0.726 ft/day) was used.

Solving the equation with these inputs, a sustainable well yield of 0.0639 gpm or 92.1 gpd was calculated.

No total dissolved solids (TDS) samples have been collected to date. As a conservative measure, a TDS concentration of less than 1,000 mg/L will be assumed for the first water bearing zone.

Using the groundwater classification system of RECAP (LDEQ 2003), which is based on the current use of the aquifer, the TDS present, and the specific yield, the first

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groundwater bearing zone beneath the Site is designated as Groundwater Classification 3A (non-drinking water).

3.0 Nature and Extent of Contamination

3.1 Study Area Soil Investigation

Numerous soil investigations have been conducted in the railbed area of the derailment (i.e., the study area). As a result of these investigations, the extent of the soil impacts has been adequately defined and an area of investigation (AOI) has been identified in accordance with RECAP as discussed below.

In order to identify the AOI for soils, the COC with the largest mapped areal distribution was selected. It can be assumed that all other COC would fall within the area defined in this manner. Limiting RECAP SS were utilized to produce an AOI map which is included as Figure 6. This AOI reflects the incorporation of all analytical data collected through August 2004.

The AOI for this site was created utilizing 1,2-dichloropropane as the primary COC. 1,2-Dichloropropane is the primary COC at the Site because of its low method reporting limit relative to the other COC and the frequency with which it exceeded the limiting RECAP Screening Standard (SS; 0.042 mg/kg). Other COC such as phenol, dicyclopentadiene, toluene diisocyanate, and acrylic acid were also considered in defining the AOI. Accordingly, the overall AOI is conservatively estimated at boring locations where the limiting RECAP SS of any COC has been exceeded at any sample interval.

Appendix B contains the railbed cross sections and isoconcentration maps that were presented in the Supplemental Railbed Site Investigation Report June 2002 (ARCADIS 2002). Three 1,2-dichloropropane cross sections were updated (Section 1, Section A, and Section C) with data from the vertical delineation borings DB-1 and DB-2. The cross sections in Appendix B depict the current understanding of the conditions beneath the railbed.

The railroad right of way is generally 50 feet from the centerline of the track, except that it is approximately 70 feet south and 90 feet north of the centerline of the track in the area of the AOI. Because impacted soil exists inside and outside the right of way, two AOI were defined for the Site. The area of impacted soil inside the right of way is compared to industrial RS and is referred to as AOI_i. The area of impacted soil

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immediately outside the right of way is compared to non-industrial standards and is referred to as AOI_{ni}. Because the two AOI are contiguous, a single acreage of impacted soil was calculated to be approximately 0.85 acre (Figure 6).

Detailed discussions of the soil sampling activities and results can be found in the reports entitled *Site Investigation Report of the Railbed Area* (ARCADIS 2002a), *Supplemental Railbed Site Investigation Report - June 2002* (ARCADIS 2002c), and *Additional RECAP Environmental Site Investigation* (ARCADIS 2004).

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3.2 Groundwater Investigation

3.2.1 Groundwater Sampling

A groundwater monitoring network consisting of permanent monitor wells was installed at and around the Site to determine if impacts to groundwater have occurred. Six monitor wells were initially installed as part of the program (MW-1, MW-2, MW-4/4R, MW-5, MW-6, and MW-7). The initial monitor well installation activities were initiated in December 2000 and were completed in January 2001. Monitor Well MW-4 was plugged and abandoned in August 2001 due to access issues and a replacement well, Monitor Well MW-4R, was installed. During the August 2004 Additional RECAP Environmental Site Investigation activities, a permanent monitor well (Chicot Well) was installed into the Chicot aquifer in the area of the highest soil impacts to determine if these impacts are reaching that aquifer. All monitor wells are sampled on a semiannual basis and are analyzed for the short list of parameters.

Figure 4 presents the locations of the seven monitor wells installed at the Site. Monitor Wells MW-1, MW-2, MW-3, MW-4R, MW-5, and MW-7 are screened in the first water bearing zone across the Site, Monitor Well MW-6 is screened in the second water bearing zone, and the Chicot Well is screened in the Chicot aquifer beneath the Site. The location of Monitor Well MW-1 was selected to represent an upgradient location of the derailment area. The locations of Monitor Wells MW-2, MW-4R, MW-5, MW-6, and MW-7 were selected to represent areas immediately adjacent to or within the impacted area, and as discussed above, the Chicot Well was installed in the area of the highest soil impacts to determine if these impacts are reaching that aquifer.

3.2.2 First Water Bearing Zone Water Quality

Appendix C contains summaries of the groundwater analytical data for the Site. As shown in the analytical summary tables, 1,2-dichloropropane, caprolactam, and aluminum are the three constituents that have been detected at concentrations above their respective RECAP SS in the monitor wells screened in the first water bearing zone. MW-4R is the only monitor well where 1,2-dichloropropane has been detected, with concentrations of 1,2-dichloropropane fluctuating between <0.001 mg/L and 0.008 mg/L. During the most recent sampling event (April 2006), 1,2-dichloropropane was detected at a concentration of 0.0025 mg/L, which is half the RECAP screening standard of 0.005 mg/L. 1,2-Dichloropropane was not detected during the previous two groundwater sampling events (August 2004 and April 2005). Although an RS was established in the MO-2 Risk Assessment for 1,2-dichloropropane in shallow groundwater at the Site, based on the current data, corrective action for 1,2-dichloropropane in shallow groundwater is not warranted.

Caprolactam was detected in all monitor wells except MW-6 (second water bearing zone well) during the February 2002 and April 2005 sampling events. It is believed that the detection of caprolactam in the samples was a result of the use of nylon string when sampling the wells. This is supported by the fact that caprolactam was not detected in MW-6, which is sampled using dedicated polyethylene tubing connected to a check valve instead of nylon string connected to a disposable bailer. Samples of string, and de-ionized water that had a length of string exposed in it for an hour, were analyzed for caprolactam and were reported with significant concentrations of that compound. Thus, it is concluded that the reported caprolactam in the groundwater sample is due to the bailer string and is not related to the derailment.

Aluminum, which is naturally occurring, was detected in groundwater from all shallow monitor wells at total concentrations ranging from 0.0447 J to 127 J mg/L and dissolved concentrations ranging from 0.0254 J to 0.142 J mg/L (February 2001 to April 2005). The maximum detected concentration of aluminum for total samples (127 J mg/L) exceeded the GW_{SS} of 3.7 mg/L. However, the maximum detected concentration of aluminum for dissolved samples (0.142 J mg/L) is less than the GW_{SS}. The higher concentrations of aluminum in the total samples are not unexpected due to the presence of "fines" (i.e., sand and/or silt particles) in the groundwater samples. Inorganics such as aluminum, many of which are naturally occurring at low concentrations, are included in the molecular composition of the sand/silt particles. The objective of filtering a sample prior to dissolved analyses is to remove the "fines" such that the resulting analytical results are representative of the groundwater only. Thus, it is concluded that the reported total aluminum concentrations in the groundwater samples are actually representative of soils, not groundwater.

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Based on the results of semiannual groundwater sampling at the Site, shallow groundwater has not been impacted above RS and corrective action is not warranted for shallow groundwater in the derailment area. Therefore, shallow groundwater is not a medium of concern at the Site and will not be addressed in the CAS.

3.2.3 Second Water Bearing Zone Water Quality

Appendix C contains summaries of the groundwater analytical data for the Site. No volatile organic compounds (VOCs) or semivolatile organic compounds (SVOCs) have been detected in the monitor well (MW-6) screened in the second water bearing zone. Aluminum was detected during the initial sampling event (February 2001) at a concentration above the RECAP SS; however, concentrations of aluminum from subsequent sampling events have been below the RECAP SS. The single aluminum exceedance of the RECAP SS is believed to be due to siltation and is not reflective of groundwater conditions. Therefore, based on the results of semiannual groundwater sampling at the Site, the second water bearing zone has not been impacted by the derailment and will not be addressed in the CAS.

3.2.4 Chicot Aquifer Water Quality

Appendix C contains the analytical data summary tables from the August 2004 to April 2006 sampling of the Chicot Well at the Site. As shown in these tables, no VOCs or SVOCs were detected in the Chicot Well. Therefore, based upon the results of these groundwater monitoring events, the Chicot aquifer has not been impacted by the derailment and will not be addressed in the CAS.

3.3 Tributary Investigation

Chemicals released from the derailment, as well as materials used during the firefighting operations, impacted the surface water and sediments in parts of the tributary. In an effort to mitigate downstream impacts and remediate the impacts to the tributary surface water and sediment, the following activities were performed:

- Earthen dams and levees were constructed to contain impacted surface water;
- Impacted surface water was removed from the tributary;
- Sediments, surficial soils, and muck from the bottom and sides of the tributary were removed; and

- Confirmation samples of the surface water and sediment were collected.

Although concentrations of COC were detected in surface water and sediment of the tributary shortly after the derailment, these COC did not persist in subsequent sampling events. The *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b) evaluated the latest (September 2001) tributary surface water data at that time to evaluate the water quality in the tributary. Based on the results of the MO-2 evaluation, corrective action for tributary surface water was not warranted at the Site for the protection of human health.

The most recent tributary surface water and sediment sampling was conducted in April 2005 as part of a turtle investigation at the derailment site. Surface water and sediment samples were collected from the following locations within the tributary:

- TS-BKG (background location at Highway 757 bridge);
- TS1-04 (upstream);
- TS1-02;
- TS2-02; and
- TS3-03.

Tables 1 and 2 present the April 2005 tributary surface water and sediment data. As shown in Table 1, 1,2-dichloropropane was the only derailment-related constituent detected in the tributary surface water. With the exception of the background location (TS-BKG), 1,2-dichloropropane was detected at all sample locations at concentrations ranging from 0.035 mg/L (TS3-03) to 0.92 mg/L (TS1-02). All reported concentrations of 1,2-dichloropropane in the tributary surface water were above the Risk-Based Concentration in Surface Water (SWNDW) of 0.005 mg/L. Figure 7 depicts the tributary surface water data.

As shown in Table 2, 1,2-dichloropropane was also the only derailment-related constituent detected above its laboratory reporting limit in the tributary sediments. 1,2-Dichloropropane was detected at sample locations TS1-02, TS1-04, and TS2-02 at concentrations of 0.006 mg/L, 0.070 mg/L, and 0.002 J mg/L, respectively. These concentrations were below the sediment RS for recreational exposure (SD_r) and fish ingestion (SD_f), which are presented in Table 3. Table 4 presents equations and sample

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calculations for risk-based concentrations in sediment. Cyanide was only reported at the background location (TS-BKG) at a concentration of 0.179 J mg/L, which is below the laboratory reporting limit of 0.5 mg/L and its sediment RS. Figure 8 depicts the tributary sediment data.

Surface water and sediment in the tributary were resampled in June 2005 to further evaluate the surface water exceedances of the 1,2-dichloropropane SWNDW. In addition to collecting surface water and sediment samples from the locations listed above, surface water and sediment samples were also collected from a location at the mouth of the tributary where it empties into Bayou des Cannes (Trib-05). The surface water and sediment analytical results are presented in Tables 1 and 2.

As shown in Table 1, 1,2-dichloropropane was the only derailment-related constituent detected in June 2005 surface water samples from the tributary. With the exception of the background location (TS-BKG), 1,2-dichloropropane was detected at all sample locations at concentrations ranging from 0.016 mg/L (Trib-05) to 0.17 mg/L (TS1-04). All reported concentrations of 1,2-dichloropropane in the June 2005 tributary surface water samples were above the SWNDW of 0.005 mg/L. Figure 7 depicts the tributary surface water data.

As shown in Table 2, 1,2-dichloropropane was the only derailment-related constituent detected in the June 2005 tributary sediment samples. 1,2-Dichloropropane was detected at sample location TS1-02 at an estimated concentration of 0.003 mg/L, which is below the laboratory reporting limit of 0.005 mg/L. 1,2-Dichloropropane was not detected in any other tributary sediment samples. Cyanide was only reported in the duplicate sample from location TS1-04 at a concentration of 0.11 B mg/L, which is below the laboratory reporting limit of 0.5 mg/L. Figure 8 depicts the tributary sediment data.

A review of the April and June 2005 tributary data reveals that concentrations of derailment-related constituents in the tributary sediments are below the sediment RS for recreational exposure (SD_r) and fish ingestion (SD_f). With the exception of the background sampling location, concentrations of 1,2-dichloropropane at all tributary surface water sampling locations remain above the RECAP SWNDW of 0.005 mg/L.

3.4 Fate and Transport/Natural Attenuation Evaluation of Site Constituents in Soil

The following is a discussion of various characteristics of COC at the Site that bear on their potential for migration and/or degradation. This information provides a basis for

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qualitatively evaluating the potential for changes in mass due to natural physical and biological transformations in COC with time and travel. No attempt has been made to quantitatively evaluate past or future changes in mass as a result of these characteristics.

Soil sorption index is measured by the soil organic carbon-water partitioning coefficient (Koc). The Koc measures a chemical's tendency to be strongly attached, by chemical or physical bonds, to soil particle surfaces. The units of Koc are generally milliliters of chemical per gram of organic carbon. Higher Koc values (e.g., 1,000) indicate a stronger attachment to soil and a lesser tendency for the chemical to move, except through physical movement of the sediment. Conversely, chemicals with lower Koc values tend to desorb and move with water resulting in higher transport.

Acrylic Acid

Acrylic acid is very soluble in water and has a low affinity for absorption to soils and aquifer materials (Koc value of 43 cubic centimeters per gram [cm^3/g; Table 5]; U.S. National Library of Medicine [USNLM] 2005). Acrylic acid has a Henry's Law constant of $3.2x10^{-7}$ atmospheres-cubic meters per mole ($atm\text{-}m^3/mol$), which suggests that it is essentially non-volatile under moist conditions. However, the vapor pressure of acrylic acid is 3.97 millimeters (mm) mercury (Hg), suggesting that it can volatilize from dry soils or at the surface.

Acrylic acid is not stable in the atmosphere, as it reacts with photochemically produced hydroxyl radicals and ozone, resulting in rapid degradation. There is no potential for long-range atmospheric transport of acrylic acid because it has an atmospheric lifetime of less than 1 month.

When released into water, acrylic acid readily biodegrades. The fate of acrylic acid in water is controlled by both chemical and microbial degradation. In natural systems, acrylic acid is rapidly oxidized, so it can potentially deplete dissolved oxygen concentrations if discharged in large quantities into a body of water. Acrylic acid is readily degraded under both aerobic and anaerobic conditions.

Acrylic acid has a log octanol-water partitioning coefficient of 0.35, which suggests that bioconcentration in aquatic organisms is unlikely. Acrylic acid had not been reported to biomagnify in the food chain (INCHEM 1997).

The acrylic acid released at the Site polymerized under natural conditions and was found as soft plastic-like pellets. This caused Union Pacific to apply for a treatability variance in March 2002 because the acrylic acid was essentially immobilized. An addendum to the treatability variance, which reflects the results of this study, was submitted to LDEQ on February 6, 2006.

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Chloromethane

Chloromethane has a Koc value of 25.10 cm^3/g (Table 5), suggesting that it will have high to very high mobility in soil and will leach into groundwater. Volatilization of chloromethane from moist soil surfaces is expected to be an important fate process given a Henry's Law Constant of $8.82x10^{-3}$ atm-m^3/mol (USNLM 2005). Field and laboratory results demonstrate that several halogenated aliphatics may biodegrade slowly under anaerobic conditions, but not under aerobic conditions (USNLM 2005).

1,2-Dichloropropane

Based on a Koc value of 47 cm^3/g (Table 5), 1,2-dichloropropane is expected to have very high mobility in soil. Volatilization of 1,2-dichloropropane from moist soil surfaces is expected to be an important fate process given a Henry's Law constant of $2.82x10^{-3}$ atm-m^3/mol. The potential for volatilization from dry soil surfaces may exist based upon a vapor pressure of 53.3 mm Hg. Biodegradation of 1,2-dichloropropane does not proceed at significant rates under aerobic conditions due to the inherent toxicity of the compound. However, degradation via reductive dechlorination under anaerobic conditions has been well documented (Tesoriero et al. 2001). 1,2-Dichloropropane is expected to be resistant to permanganate oxidation, as are many chlorinated alkanes, and is considered to be moderately susceptible to hydroxyl radical oxidation.

Phenol

Based on a Koc value of 28.8 cm^3/g (Table 5), phenol is expected to have high mobility in soil. Volatilization of phenol from moist soil surfaces is not expected to be an important fate process. Phenol is not expected to volatilize from dry soil surfaces based upon a measured vapor pressure of 0.35 mm Hg. Phenol readily degrades in soil under both aerobic and anaerobic conditions (USNLM 2005). Phenol is susceptible to oxidation, including oxidants such as the permanganate ion and hydroxyl radical (generated by Fenton's reagent).

Disodium Iminodiacetate

Disodium Iminodiacetate has a Koc value of 2.2 cm^3/g (Table 5) and a water solubility of $1x10^6$ mg/L at 25 degrees Celsius (°C) (ARCADIS 2001). Typically, organic compounds with high water solubilities and low Kocs are highly mobile. Based on a Henry's Law Constant of $1.51x10^{-11}$ atm-m^3/mol, disodium iminodiacetate would be considered a semivolatile compound (ARCADIS 2001).

Dicyclopentadiene

Dicyclopentadiene has a calculated Koc of 894 cm^3/g (Table 5) which suggests that dicyclopentadiene may adsorb to soil at significant concentrations and is expected to display low mobility in groundwater. The Henry's Law Constant is estimated to be 0.0107 atm-m^3/mol, suggesting that volatilization from soil surface to the atmosphere may be a rapid process. Neither hydrolysis nor biological degradation in soil is expected to be significant fate processes due to dicyclopentadiene being sparingly soluble in water (20 mg/L at 20°C). Dicyclopentadiene is susceptible to oxidation via permanganate as well as being readily oxidized by the hydroxyl radical.

Hexane

Estimates of Koc values for hexane range from 150 (USNLM 2005) to 890 cm^3/g (USEPA Region III) suggesting that hexane may have low to moderate mobility in groundwater. Volatilization from moist soil surfaces is expected to be an important fate process given a Henry's Law constant of 1.81 atm-m^3/mol (USNLM 2005). Hexane is readily biodegradable under aerobic conditions; however, volatilization from soil is expected to be the dominant environmental transport process (USNLM 2005).

Naphthalene

Estimates of Koc values for naphthalene vary from 440 to 830 cm^3/g measured in five different soils depending on soil type. This range suggests that naphthalene has moderate to low mobility in groundwater. Volatilization of naphthalene from moist soil surfaces is expected to be an important fate process given a Henry's Law Constant of $4.4x10^{-4}$ atm-m^3/mol. The estimated volatilization half-life for naphthalene from soil is 1.1 days and 14 days when incorporated at a depth of 1 to 10 centimeters, respectively. Naphthalene has been shown to degrade fairly rapidly in soils previously exposed to naphthalene with reported half-lives in the range of 2 to 18 days (USNLM 2005).

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Toluene Diisocyanate

Based on a Koc value of 9114 cm^3/g, toluene diisocyanate is not expected to be mobile in soil. It has a very short half-life in air, particularly moist air. Toluene diisocyanate reacts readily with compounds containing active hydrogens, such as water, acids, and alcohols; therefore, leaching is not significant (USNLM 2005). Toluene diisocyanate is not expected to volatilize from dry soil surfaces based upon a vapor pressure of 8×10^{-3} mm Hg (USNLM 2005).

4.0 Human Health Risk Assessment Summary

A Management Option (MO) 2 Risk Assessment for the Railbed Area was completed and submitted to LDEQ in November 2002. Although the extent of soil impacts in the railbed area have changed somewhat since the risk assessment was completed, relevant sections of the risk assessment are summarized below.

4.1 Summary of Constituents of Concern

The term COC is used by RECAP and the USEPA to describe those constituents on which the risk assessment will focus (i.e., potential risk drivers). COC are selected to focus the exposure evaluation on the constituents that potentially pose the greatest risks to human health and the environment. COC were selected according to relevant agency guidance (USEPA 1989; LDEQ 2000).

All constituents detected in environmental media at the Site were evaluated to be retained as COC based on the following consideration:

- A comparison of site-related constituent concentrations to RECAP screening standards was utilized to identify the COC that were to be carried over to the next level of assessment (e.g., MO-2). Constituents with concentrations greater than the screening standards were retained as COC.

Tables 1 through 26 of the *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b) contain summaries of the soil analytical data available at the time of submittal for the two AOI. The area of impacted soils falls inside and immediately outside the railroad right of way. The area inside the right of way was evaluated under industrial land use (AOI_i), while the area of impacted soils immediately outside the railroad right of way was evaluated under non-industrial land use (AOI_{ni}). Based on

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Site information, AOI_i and AOI_{ni} meet all of the criteria for management under RECAP Screening Option (SO) and MO-2.

Based on a comparison of maximum detected constituent concentrations of the preliminary COC in AOI_i soils with RECAP SS for industrial land use (Tables 33 and 34 of the MO-2 Risk Assessment), 1,2-dichloropropane, chloromethane, hexane, acrylic acid, dicyclopentadiene, disodium iminodiacetate, naphthalene, phenol, and toluene diisocyanate in soil are considered COC at the Site that warrant further evaluation under MO-2.

Based on a comparison of maximum detected constituent concentrations of the preliminary COC in AOI_{ni} soils with RECAP SS for non-industrial land use (Tables 35 and 36 of the MO-2 Risk Assessment), 1,2-dichloropropane, dicyclopentadiene, phenol, and aluminum are considered COC at the Site that warrant further evaluation under MO-2.

Although soil data collected since the submittal of the MO-2 Risk Assessment have updated the understanding of the horizontal and vertical extent of contamination in the railbed area, these data do not affect the selection of COC for the railbed area.

Tables 31 and 32 of the *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b) contain summaries of the most recent tributary surface water analytical data at the time of submittal for the Site. 1,2-Dichloropropane, aluminum, and 1,2,3,4,6,7,8,9-octachlorodibenzo-p-dioxin (OCDD) were the only constituents detected. RECAP SWNDW SS have previously been calculated and presented to LDEQ (ARCADIS 2002a). 1,2-Dichloropropane was detected below its RECAP SWNDW SS of 0.005 mg/L, while aluminum exceeded its RECAP SWNDW of 2.5 mg/L at one location. To determine the effects of dioxins, each chemical is given a toxicity equivalency factor (TEF). The dioxin-like toxicity of a chemical is measured by its dioxin toxic equivalent (TEQ). In a mixture of these chemicals, dioxin TEQs for each chemical are added together to give a total TEQ. The total dioxin TEQ for surface water in the tributary was 0.0059 picogram per liter (pg/L) and did not exceed the RECAP SWNDW SS of 0.07 pg/L for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), the most harmful dioxin. (This TEQ is also less than the LDEQ Numerical Criteria for a non-drinking water supply of 0.72 pg/L.) Because aluminum was the only constituent detected above its RECAP SWNDW SS, it was identified as the only COC in tributary surface water.

Table 1 presents the April and June 2005 tributary surface water analytical summary. Based on a comparison of maximum detected concentrations in surface water with the RECAP SWNDW, 1,2-dichloropropane is identified as a COC in tributary surface water. Therefore, aluminum and 1,2-dichloropropane have been identified as COC in tributary surface water.

Table 2 presents the April and June 2005 tributary sediment analytical summary. Based on a comparison of maximum detected concentrations in tributary sediment with the sediment RS, no COC were identified. Therefore, tributary sediment does not warrant further evaluation.

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4.2 Exposure Assessment

Exposure assessment is the process of estimating the frequency, duration, and degree of human exposure to a chemical in the environment. This exposure assessment section presents the potential mechanisms of migration and a conceptual site model (CSM) for the Site and provides the basis for exposure estimates, or daily intakes, for each identified receptor. According to the regulatory guidance and requirements, the risk assessment should identify and evaluate all reasonable exposure pathways, exposure points, and receptors.

Exposure pathways require five elements to be considered complete:

- A source and mechanism of chemical release;
- An environmental transport medium for the released chemical (e.g., groundwater);
- A point of potential exposure of receptors (human or ecological) to transported chemicals;
- Receptors located at the exposure points; and
- An uptake route (e.g., inhalation, ingestion, or dermal absorption) for the COC at the point of exposure.

If any of the above five elements are absent or considered insignificant, then the exposure pathway would be considered incomplete. Only complete exposure pathways were quantitatively addressed in the exposure assessment.

4.2.1 Potential Mechanisms of Migration

There are several mechanisms by which chemical constituents may migrate through environmental media. The mechanisms of migration for COC at the Site are discussed in this section from a conceptual standpoint, together with a discussion of constituent persistence and transformations that may occur in the source or transport media.

4.2.1.1 Migration in Soil

Constituents migrate in the subsurface soil primarily in the dissolved phase. Solubility in water, area rainfall characteristics, the tendency to bind to soil and organic carbon, type of soil (particle size distribution, clay content, organic material content, porosity, and permeability), and the depth to groundwater are significant factors in determining the potential for COC to migrate from soil to groundwater. The more soluble constituents may migrate through soil to the groundwater with infiltrating precipitation. Typically, organic constituents with high water solubilities and low Koc are particularly susceptible to leaching. The more volatile constituents, or those strongly adsorbed to dust, may migrate into air.

The nature of the soils at a site significantly affects transport within the soil. Clays and minerals exhibit adsorptive behavior, while organic matter is capable of both adsorption and absorption. Coarse sands are very poor at sorbing chemicals. Because sorption is an equilibrium process, some of the sorbed constituents may "desorb" from the particles into the dissolved phase and be released into the soil moisture and be transported with infiltrating precipitation. Acrylic acid, chloromethane, 1,2-dichloropropane, phenol, and disodium iminodiacetate are very mobile liquids. In contrast, dicyclopentadiene adsorbs to soil and displays low mobility. Adsorption is also an important fate process for hexane. The sorption of naphthalene to soil is low to moderate depending on the organic carbon content of the soil. If toluene diisocyanate is released on wet land, it is rapidly degraded through a reaction with water (USNLM 2005).

4.2.1.2 Migration in Groundwater

Soluble compounds can migrate from soil to groundwater with infiltrating precipitation. In groundwater, compounds may remain in the water column or adsorb to soil particles. Solubility and Koc are two of the most important properties affecting constituent migration in groundwater. Acrylic acid and disodium iminodiacetate are soluble in water, while chloromethane and 1,2-dichloropropane volatilize from water. Volatilization from water is an important fate process for dicyclopentadiene, but its Koc value of 894 cm^3/g suggests that sorption to sediment or suspended organic matter may

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be more important. Volatilization and adsorption are also important fate processes for hexane. Releases of naphthalene into water are lost due to volatilization, biodegradation, adsorption, and photolysis. Phenol will not adsorb to sediment and particulate matter in the water column, but will primarily be removed by degradation. If released to water, toluene diisocyanate is not expected to leach or adsorb to solids due to its rapid degradation reaction with water (USNLM 2005).

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4.2.1.3 *Migration into Air*

Two processes control migration of constituents from soils into the air. Constituents may volatilize directly into the air, or constituents sorbed to surface soil may migrate into the air through the generation of dust, either through wind erosion or mechanical means. Constituents released into the atmosphere are subject to transport and dispersion by prevailing winds. Chloromethane, 1,2-dichloropropane, dicyclopentadiene, hexane, and naphthalene volatilize from soil and groundwater. Phenol may volatilize from soil, but will primarily be removed through biodegradation. Phenol will not volatilize from water. Volatilization of acrylic acid from moist soil surfaces is not expected to be an important fate process, and volatilization from water surfaces is expected to be slow. Toluene diisocyanate will not readily volatilize from soil surfaces, and because it reacts with water, volatilization from water surfaces should not be an important fate process (USNLM 2005).

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4.2.2 Conceptual Site Model

The CSM is an important tool for obtaining an understanding of site exposure pathway dynamics. It depicts the Site and its environment(s) and delineates potential chemical sources, chemical release and transport mechanisms, affected media, migration routes, and potential human and ecological receptors. The CSM provides a framework for problem definition and aids in the identification of data gaps. More importantly, it identifies key exposure pathways and associated media on which to focus assessment activities.

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Exposure can occur only when the potential exists for a receptor to directly contact released constituents or when a mechanism exists for the released constituents to be transported to a receptor. Without exposure, there is no risk. For the Site, all potential exposure pathways have been combined into an integrated and dynamic CSM as shown on Figure 9. The CSM indicates potentially complete and incomplete pathways and represents the cumulative information needed to evaluate whether exposure pathways warrant further consideration. Complete pathways are designated by a solid dot, while an open space designates incomplete pathways. The CSM is based on site-specific information that combines information on primary sources of constituents, constituent release mechanisms, transport media, potential receptors, exposure routes, and potentially complete exposure pathways.

An industrial exposure scenario (AOI_i) was considered for the area of impacted soil inside the railroad right of way. A non-industrial exposure scenario (AOI_{ni}) was considered for the area of impacted soil immediately outside the right of way. The CSM identifies the train derailment as the primary release mechanism of constituents contained within the train cars to the railbed/soil at the Site. Secondary release mechanisms and the resulting media of concern are runoff/erosion into the tributary surface water/sediment, direct contact with surface soil and potential surface soil, and infiltration/percolation into first water bearing zone groundwater and Chicot aquifer groundwater. Potential receptors for AOI_i include current and future Site visitors and railroad workers that may be exposed to surface soil and potential surface soil, current and future recreational receptors that may be exposed to tributary surface water/sediment, and hypothetical future recreational receptors via groundwater/surface water exchange. Potential receptors for AOI_{ni} include current and future residential receptors that may be exposed to surface soil and potential surface soil and future residential receptors that may be exposed to Chicot aquifer groundwater. Exposure routes include ingestion, dermal contact, and inhalation.

No residential exposure is considered applicable to the COC that have been identified in shallow groundwater. A recent Louisiana Department of Transportation and Development (LDOTD) well survey within a 1-mile radius of the Site was conducted (Appendix D). Two domestic wells (screened at depths of 170 and 182 ft bls), two irrigation wells (screened at depths of 278 and 279 ft bls), and one monitor well, which is plugged and abandoned, were found within a 1-mile radius of the Site. The groundwater classification for the first water bearing zone is groundwater classification 3A (non-potable). Therefore, human exposure to shallow groundwater is unlikely under a residential scenario. However, future off-site residential exposure to Chicot aquifer groundwater (conservatively designated as Groundwater Classification 1B) is a potentially complete exposure pathway in the event COC beneath the railbed reach this water bearing zone in the future.

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4.2.2.1 *Summary of Potential Receptors and Exposure Pathways*

Based on available site-specific information, the receptors, exposure media, and exposure routes considered to be potentially complete and to warrant potential quantification are summarized below.

Receptor	Medium	Exposure Pathway
A. Current and Future Site Visitor	Surface Soil and Potential Surface Soil	Ingestion, Dermal Contact, Inhalation
B. Current and Future Railroad Worker	Surface Soil and Potential Surface Soil	Ingestion, Dermal Contact, Inhalation.
C. Current and Future Residential Receptor	Surface Soil and Potential Surface Soil	Ingestion, Dermal Contact, Inhalation.
D. Current and Future Recreational Receptor	Tributary Surface Water	Ingestion.
E. Current and Future Recreational Receptor	Tributary Sediment	Ingestion, Dermal Contact.
F. Hypothetical Future Recreational Receptor	First Water Bearing Zone Groundwater/Surface Water	Ingestion.
G. Hypothetical Off-Site Residential Receptor	Chicot Aquifer Groundwater	Ingestion, Inhalation.

4.3 Toxicity Assessment

The toxicity assessment evaluates the toxicity of the COC by exploring the relationship between dose and toxicological response for potential receptors. The information obtained in the toxicity assessment is used in the calculation of RS.

4.3.1 Human Health Toxicity Values

The principal indices of toxicity that are used in risk assessments are the oral reference dose (RfD) and reference concentration (RfC) for noncancer effects and the oral and inhalation cancer slope factors (CSF) or the inhalation unit risk (UR_i) for cancer

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effects. The values are derived by the USEPA for the most commonly occurring and the most toxic chemicals generally associated with chemical releases to the environment. As reported in RECAP (LDEQ 2000), toxicity values are obtained from the following hierarchy of sources: (1) USEPA's Integrated Risk Information System (IRIS), an on-line database of toxicity information which is updated on a monthly basis (USEPA 2002a); (2) USEPA's Health Effects Assessment Summary Tables (HEAST) (USEPA 1997); (3) USEPA Region III Risk-Based Concentration Tables (USEPA 2002b); (4) USEPA Region IX Preliminary Remediation Goals Tables (USEPA 2000); or (5) USEPA Region VI Human Health Medium-Specific Screening Levels (USEPA 2001b).

4.3.2 Toxicity Summary

1,2-Dichloropropane is considered Group B2 (probable human carcinogens), and although chloromethane is considered Group D (not classifiable as to its human carcinogenicity), numerous rodent studies provide suggestive information of carcinogenic risk (USEPA 2002a). Toluene diisocyanate is classified by the California EPA as Group B2 (CalEPA 1999). Because RS for carcinogenic constituents are based on a target risk level of 10^{-6}, it is not necessary to adjust (e.g., for additivity) RS that are based on carcinogenic health effects (LDEQ 2000). It is assumed that setting a 10^{-6} risk level for individual constituents and pathways generally will lead to cumulative cancer risks within the acceptable risk range of 10^{-6} to 10^{-4} (LDEQ 2000).

The COC for this Site also produce noncarcinogenic effects. The target organ/system for hexane is the nervous system. The target organs/systems for acrylic acid are body weight and nose (USEPA 2002a). The target organ/system for dicyclopentadiene was not available from the source that provided the RfD value and, therefore, is not available. The target organ/system for disodium iminodiacetate is the reproductive system (ARCADIS 2001b; Monsanto 1987). The target organs/systems for naphthalene are body weight and nose (USEPA 2002a). The target organ/system for phenol is fetal body weight (USEPA 2002a). The target organ/system for toluene diisocyanate is the lung (USEPA 2002a). In accordance with RECAP, RS for constituents that produce non-carcinogenic effects on the same target organ/system shall be modified to account for potential additive health effects associated with exposure to multiple constituents (RECAP, Appendix G). In this case, modification to account for additivity is required.

For noncarcinogens, the MO-2 risk-based RS were based on a hazard quotient of 1.0 and provide protection for exposure to a single constituent via a single medium. The application of MO-2 risk-based RS at a site where multiple constituents are present

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could result in a hazard quotient of greater than 1.0. To address this concern, the MO-2 risk-based RS for constituents that produce noncarcinogenic effects on the same target organ/system shall be modified to account for potential additive health effects associated with exposure to multiple constituents. To identify the risk-based RS requiring modification, the constituents detected at the Site shall be grouped according to the critical effect (target organ/system) listed as the basis for the RfD and RfC (USEPA 2002a).

When more than one noncarcinogenic constituent detected in soil affects the same target organ/system, the RS ($Soil_i$) for those constituents shall be divided by the number of constituents present in the group. Hexane, acrylic acid, dicyclopentadiene, disodium iminodiacetate, naphthalene, phenol, and toluene diisocyanate are COC that produce noncarcinogenic effects (USEPA 2002a; ARCADIS 2001b; Monsanto 1987).

Soil: Hexane, Acrylic Acid, Dicyclopentadiene, Disodium Iminodiacetate, Naphthalene, Phenol, Toluene Diisocyanate

Additivity - Nervous system: Hexane

Body weight: Acrylic Acid, Naphthalene.

Nose: Acrylic Acid, Naphthalene.

Reproductive system: Disodium Iminodiacetate.

Fetal body weight: Phenol.

Lung: Toluene Diisocyanate.

The $Soil_i$ for acrylic acid and naphthalene should be divided by 2 to account for cumulative effects to body weight and nose due to simultaneous exposure to both COC. Therefore, modifications of the $Soil_i$ RS for acrylic acid and naphthalene, to account for additive effects, are shown in Table 39 of the *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b).

Modifications to account for additive effects do not apply to GW_3 (RECAP Appendix G, page G-2). Therefore, the GW_{3NDW} RS should be used as they appear in RECAP Table 3 and in Table 42 and Table D-6, Appendix D, of the *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b).

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4.4 Risk Characterization

This risk characterization, which was originally presented in the MO-2 Risk Assessment, evaluated the soil concentrations for the protection of the first water bearing zone, which is designated as Groundwater Classification 3A (non-drinking water).

During the site investigation, soil samples were collected from the most heavily impacted areas (locations S-ES-04, N-ES-07, N-ES-11, N-ES-12) of the Site and analyzed for the short and extended list of constituents by SPLP. The SPLP data can be utilized in the calculation of site-specific $Soil_{GW}$ RS using the following relationship:

$$SPLP_{concentration} \leq (GW\ RS)(DF)$$

If the SPLP concentration is less than or equal to the GW RS multiplied by the appropriate dilution factor (DF), then the soil concentration is acceptable for the soil to groundwater pathway.

Because the first water bearing zone beneath the site is classified as Groundwater Classification 3A, the following relationship would apply:

$$SPLP_{concentration} \leq (GW_{3NDW})(DF_{Summers})$$

Tables 23 and 24 of the *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b) report the results for the soil SPLP analytical results. Using the above relationship for application of SPLP data, the GW_{3NDW} RS may be multiplied by a DF as determined by the Summers model to account for vertical migration of COC (a default value of 20 is recommended in RECAP). A longitudinal DF3 was conservatively not applied given the close proximity of the tributary. Excluding 1,2-dichloropropane, the concentrations of all constituents reported from SPLP analyses are less than these adjusted values (Table 38 of the Management Option 2 Risk Assessment). Therefore, it can be conservatively assumed that these constituents are not of concern for the soil to groundwater pathway for protection of first water bearing zone groundwater.

Maximum detected concentrations of COC in each medium were then compared to the limiting RS to determine corrective action needs at the Site. A comparison of the maximum detected concentrations of the COC in AOI_i surface soil (0-15 ft bls) to the MO-2 RS (Table 6) revealed that 1,2-dichloropropane, hexane, acrylic acid,

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dicyclopentadiene, and toluene diisocyanate exceed their limiting MO-2 RS. A comparison of the maximum detected concentrations of the COC in AOI_i subsurface soil (>15 ft bls) to the MO-2 RS (Table 7) revealed that 1,2-dichloropropane exceeded its limiting MO-2 RS. A comparison of the maximum detected concentrations of the COC in AOI_{ni} surface soil (0-15 ft bls) to the MO-2 RS (Table 8) revealed that 1,2-dichloropropane exceeded its limiting MO-2 RS.

Based on the results of the recent groundwater sampling events (Appendix C), 1,2-dichloropropane has not been detected above the RS of 0.005 mg/L in groundwater at the Site, and aluminum has been detected at concentrations less than its limiting RS of 25 mg/L. Therefore, based on the results of semiannual groundwater sampling at the Site, shallow groundwater has not been impacted above RS and corrective action is not warranted for shallow groundwater in the derailment area. Therefore, shallow groundwater is not a medium of concern at the Site and will not be addressed in the CAS.

As discussed in Section 3.3, 1,2-dichloropropane and cyanide were detected in tributary sediment at concentrations below the sediment RS. Therefore, corrective action is not warranted for tributary sediment and this medium will not be addressed in the CAS.

Additionally, as discussed in Section 3.3, all detected concentrations of 1,2-dichloropropane in tributary surface water were above the Risk-Based Concentration in Surface Water of 0.005 mg/L. Corrective action is warranted for tributary surface water; however, this medium will not be addressed in this Corrective Action Study (see Section 6.4.1).

In summary, corrective action (based on an evaluation of the soil data for protection of first water bearing zone groundwater) is warranted at the Site for the following medium and constituents:

- AOI_i Surface Soil - 1,2-dichloropropane, hexane, acrylic acid, dicyclopentadiene, and toluene diisocyanate;
- AOI_i Subsurface Soil - 1,2-dichloropropane; and
- AOI_{ni} Surface Soil - 1,2-dichloropropane.

4.4.1 Identification of RECAP Standards

Based on the results of the *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b), the following MO-2 RS were proposed as corrective action standards for the railbed area (based on an evaluation of the soil data for protection of first water bearing zone groundwater):

AOI$_i$ Surface Soil

- 1,2-Dichloropropane - 0.14 milligram per kilogram (mg/kg) ($Soil_{GW3NDW}$)
- Hexane - 270 mg/kg ($Soil_{sat}$)
- Acrylic Acid - 115 mg/kg ($Soil_i$)
- Dicyclopentadiene - 17 mg/kg ($Soil_i$)
- Toluene Diisocyanate - 0.72 mg/kg ($Soil_i$)

AOI$_i$ Subsurface Soil

- 1,2-Dichloropropane - 0.14 mg/kg ($Soil_{GW3NDW}$)

AOI$_{ni}$ Surface Soil

- 1,2-Dichloropropane - 0.14 mg/kg ($Soil_{GW3NDW}$)

4.5 Additional Risk Characterization (Protection of Chicot Aquifer Groundwater)

In response to LDEQ comments on the Corrective Action Study that was submitted to LDEQ on September 30, 2005, it was necessary to re-evaluate the results of the SPLP analyses in order to evaluate the potential for constituents in soil to leach to the Chicot aquifer (conservatively designated as Groundwater Classification 1, drinking water). Additionally, the LDEQ comments requested that all COC listed in Table 6 of the CAS Report be retained for evaluation and remedial standards developed. As shown in Table 9, the maximum detected SPLP concentrations were compared to the product of GW_1 x 20. The results of this comparison indicated that the soil concentrations of 1,2-dichloropropane, chloromethane, dicyclopentadiene, naphthalene, and phenol may not be protective of groundwater designated as Classification 1 and the soil to

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groundwater pathway cannot be eliminated from consideration for these constituents. As shown in Tables 10, 11, and 12, the following MO-2 RS are proposed as corrective action standards for the railbed area (based on an evaluation of the soil data for protection of the Chicot aquifer):

<u>AOI$_i$ Surface Soil</u>

- 1,2-Dichloropropane - 0.042 mg/kg ($Soil_{GW1}$)
- Chloromethane - 0.1 mg/kg ($Soil_{GW1}$)
- Hexane - 270 mg/kg ($Soil_{sat}$)
- Acrylic Acid - 115 mg/kg ($Soil_i$)
- Dicyclopentadiene - 0.21 mg/kg ($Soil_{GW1}$)
- Naphthalene - 1.5 mg/kg ($Soil_{GW1}$)
- Phenol - 11 mg/kg ($Soil_{GW1}$)
- Toluene Diisocyanate - 0.72 mg/kg ($Soil_i$)

<u>AOI$_i$ Subsurface Soil</u>

- 1,2-Dichloropropane - 0.042 mg/kg ($Soil_{GW1}$)
- Chloromethane - 0.1 mg/kg ($Soil_{GW1}$)
- Dicyclopentadiene - 0.21 mg/kg ($Soil_{GW1}$)

<u>AOI$_{ni}$ Surface Soil</u>

- 1,2-Dichloropropane - 0.042 mg/kg ($Soil_{GW1}$)
- Dicyclopentadiene - 0.21 mg/kg ($Soil_{GW1}$)
- Phenol - 11 mg/kg ($Soil_{GW1}$)

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4.6 Human Health Risk Assessment Conclusions

Based on the results of the MO-2 Risk Assessment (which considered soil concentrations for protection of first water bearing zone groundwater), corrective action is warranted for soil at the Site for the protection of human health and the environment for the following COC: 1,2-dichloropropane, hexane, acrylic acid, dicyclopentadiene, and toluene diisocyanate in AOI_i; 1,2-dichloropropane in AOI_{ni}.

Based on the evaluation of the soil data performed in response to January 3, 2006, LDEQ comments on the original CAS report, corrective action is warranted for soil at the Site for the protection of human health and the environment for the following COC: 1,2-dichloropropane, chloromethane, hexane, acrylic acid, dicyclopentadiene, naphthalene, phenol, and toluene diisocyanate. As shown in Table 10, disodium iminodiacetate was not detected in soil at concentrations exceeding its limiting MO-2 RS of 35,000 mg/kg and corrective action is not warranted for this COC. However, in response to LDEQ comments on the original CAS report, the limiting MO-2 RS of 35,000 mg/kg presented in Table 10 can be utilized as a remedial action goal.

Based on the results of the comparison of maximum detected concentrations of COC from the most recent tributary surface water sampling event with the SWNDW RS, corrective action for 1,2-dichloropropane in surface water is warranted at the Site for the protection of human health.

In summary, the following RS are proposed as corrective action goals:

Constituent	Remediation Goal (mg/kg)	Basis for Remediation Goal
1,2-Dichloropropane	0.042	$Soil_{GW1}$
Chloromethane	0.1	$Soil_{GW1}$
Hexane	270	$Soil_{sat}$
Acrylic Acid	115	$Soil_i$
Dicyclopentadiene	0.21	$Soil_{GW1}$
Disodium Iminodiacetate	35,000	$Soil_i$
Naphthalene	1.5	$Soil_{GW1}$
Phenol	11	$Soil_{GW1}$
Toluene Diisocyanate	0.72	$Soil_i$

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5.0 Screening Level Ecological Risk Assessment

An Ecological Risk Assessment Checklist was prepared for the Site in accordance with RECAP (LDEQ 2000) and was presented in the *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b). The AOI did not meet the criteria for exclusion from further ecological assessment because of the long-term threat of release (via surface runoff or groundwater discharge) to the adjacent tributary. Therefore, a screening level ecological risk evaluation was conducted that evaluated the potential effects of runoff to aquatic receptors in the surface water of the tributary.

Three COC, 1,2-dichloropropane, aluminum, and OCDD, were detected in tributary surface water. A comparison of the maximum detected concentrations in tributary surface water to USEPA chronic ambient water quality criteria (AWQC) (Table 43 of the *Management Option 2 Risk Assessment Railbed Area* [ARCADIS 2002b]) revealed that only aluminum exceeded the chronic AWQC. The total concentrations of aluminum, which is naturally occurring, detected in tributary surface water samples are reflective of suspended soil particles in the total metals analyses (unfiltered samples). Therefore, it is concluded that the reported total aluminum concentrations in the surface water samples are at background concentrations, actually representative of soils, not surface water, and do not pose an unacceptable risk to aquatic receptors.

These comparisons conservatively assumed no dilution within the tributary. If dilution were factored into this evaluation, risks to aquatic life would be shown to be much lower. Therefore, surface runoff or groundwater discharges to the tributary should not result in adverse impacts to aquatic biota and corrective action is not warranted at the Site for the protection of aquatic receptors.

An additional surface water and sediment investigation of the tributary was conducted during April and June 2005 according to the *Phase I Work Plan for the Assessment of Turtles at Eunice City Lake* (ARCADIS 2005). This investigation was part of an assessment of turtles that had been reported to be apparently affected with a shell disease. The final report documenting the investigation is currently being prepared. However, a summary of the data evaluation for screening level ecological risks is presented below.

Chronic ecotoxicity screening values (ESV) used to conservatively evaluate potential impacts to water column organisms included LDEQ Numerical Criteria, USEPA Region 4 chronic freshwater surface-water screening values (USEPA 2001a), secondary chronic values of Suter and Tsao (1996), and chronic aquatic life protection

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criteria calculated in accordance with LDEQ (1993). Sediment quality screening values used to conservatively evaluate potential impacts to benthic organisms included sediment quality criteria (SQC) calculated using an equilibrium partitioning approach (Fuchsman 2003). The supporting calculations for these screening values will be presented in the final report for the turtle assessment.

1,2-Dichloropropane was detected in tributary surface water at concentrations ranging from 0.035 mg/L to 0.92 mg/L during the April 2005 sampling event and at concentrations ranging from 0.016 mg/L to 0.17 mg/L during the June 2005 sampling event (Table 13). The maximum concentration of 0.92 mg/L was the only concentration that exceeded the chronic ESV of 0.525 mg/L (Table 14). However, the maximum concentration was below the chronic no observed effect concentration (NOEC) (growth) which was selected as a refined ESV for comparison (Table 14).

1,2-Dichloropropane was detected in tributary sediment at concentrations ranging from 0.002 J mg/kg to 0.07 mg/kg during the April 2005 sampling event (Table 15). 1,2-Dichloropropane was detected at one sample location (TS1-02) at a concentration of 0.003 J mg/L during the June 2005 sampling event (Table 15). The maximum concentration of 0.07 mg/L was below the calculated SQC of 0.37 mg/kg (Table 16). During the April 2005 sampling event, cyanide was detected in tributary sediment only at the background location at an estimated concentration below the standard reporting limit (0.179 J mg/kg). During the June 2005 sampling event, cyanide was only detected in the duplicate sample from location TS1-04 at an estimated concentration below the standard reporting limit (0.11 B mg/kg). Although an SQC is not available for cyanide, the COC is not considered to be of concern at the AOI.

Based on the results of the screening level comparisons for surface water, the possibility of adverse ecological effects for surface water cannot be ruled out. However, Step 3a of the USEPA ecological risk assessment guidance (Simon 2000; USEPA 2001c) allows for an incremental iteration of exposure, effects, and risk characterization which serves to refine risk estimates calculated during the screening level ecological risk assessment (SLERA). For the majority of sites, ERA activities will cease after Step 3a (Simon 2000). The maximum detected concentration of 1,2-dichloropropane in surface water is below a refined ESV, indicating that there is little likelihood for chronic effects to aquatic organisms. Additionally, it should be noted that the proposed remedial technology selected during the CAS process should serve to mitigate future releases of COC to the surface water of the tributary.

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Based on the results of the screening level comparisons for sediment, there is limited potential for COC to pose unacceptable risks to benthic organisms in the tributary. Therefore, these comparisons indicate that adverse impacts to benthic organisms are not expected and corrective action for sediment at the Site is not warranted for the protection of benthic organisms.

6.0 Remedial Action Objectives

6.1 Scope of the Remedial Action

The scope of the remedial action includes remediation of all soil that exceeds RS in soil. Other media, namely surface water and sediments, have been eliminated from consideration for the following reasons:

1. Sediment concentrations are below sediment quality screening values;

2. Surface-water concentrations only recently exceeded surface water quality screening levels. Resampling has been performed to verify these initial results; and

3. Remediation (treatment and/or containment) of "source area" soils will eliminate movement of contaminants from the source area to other media.

6.2 Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) and Other Criteria

6.2.1 Potential Chemical-Specific ARARs

The following table presents the remediation goals for the railbed area that were developed in the *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b).

COC	Remediation Goal (mg/kg)	Basis for Goal (i.e., Limiting RS)
AOI Surface Soil		
1,2-Dichloropropane	0.14	$Soil_{GW3NDW}$
Hexane	270	$Soil_{sat}$
Acrylic Acid	115	$Soil_i$
Dicyclopentadiene	17	$Soil_i$
Toluene Diisocyanate	0.72	$Soil_i$

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COC	Remediation Goal (mg/kg)	Basis for Goal (i.e., Limiting RS)
AOI Subsurface Soil		
1,2-Dichloropropane	0.14	$Soil_{GW3NDW}$
AOI Surface Soil		
1,2-Dichloropropane	0.14	$Soil_{GW3NDW}$

6.3 Remedial Action Objectives

Remedial action objectives for the Site consist of the following:

- Prevent exposure to unacceptable concentrations of COC in impacted soil via direct contact;
- Prevent release of unacceptable concentrations of COC to surface water; and
- Prevent the release of unacceptable concentrations of COC to groundwater.

6.4 Remediation Goals

6.4.1 Media of Concern

Based on the conclusions of the risk assessment for the railbed area, soil is identified as the medium requiring corrective action at the Site. Sediment is not a medium of concern based on the fact that recent samples show levels below sediment screening levels. Additionally, tributary surface water is a medium of concern, based on recent sampling. The proposed remedial technologies for soil will mitigate future releases to other media by reducing or eliminating the mass of COC in the "source" area.

6.4.2 Constituents of Concern

The COC for this CAS are those constituents that exceeded the MO-2 RS as determined in the *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b). The constituents requiring remedial action are as follows:

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AOI_i

- 1,2-Dichloropropane
- Hexane
- Acrylic Acid
- Dicyclopentadiene
- Toluene Diisocyanate

AOI_{ni}

- 1,2-Dichloropropane

6.4.3 RECAP Standards for Soil and Subsurface Soil

The RS for soil were developed in the *Management Option 2 Risk Assessment Railbed Area* (ARCADIS 2002b) and are presented in Section 6.2.1.

7.0 Identification and Screening of Remedial Technologies

This section presents the general response actions (GRAs) capable of meeting the RAOs for soil developed in Section 6.0 and summarized in Table 17. The GRAs suitable for potentially achieving the RAOs, and the technology groups and technology process options within each GRA are identified in Table 18. The technology process options are then evaluated in relation to their relative effectiveness, implementability, and relative cost, and those found inapplicable are screened out and removed from further consideration. Table 18 also presents the results of the evaluation and identifies the RAO addressed by each retained process option. The remaining applicable technology process options will be assembled into site-wide remedial alternatives and analyzed in detail in Section 8.0, Identification and Detailed Analysis of Remedial Alternatives.

7.1 General Response Actions

The GRAs considered capable of meeting the RAOs for soil include:

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- No action;
- In situ containment (stabilization and capping);
- In situ treatment (chemical, biological, and thermal); and
- Removal and treatment/disposal.

7.2 Screening Criteria

The potentially applicable remedial process options for each media were evaluated against the three screening criteria specified in LAC 33:VI.509.C.4 as follows:

- Effectiveness;
- Implementability; and
- Relative cost.

Of these criteria, the effectiveness and implementability of the technology process option are the most critical. Process options judged to be inferior in meeting these criteria were eliminated from further consideration. In cases where process options within the same technology type achieve the same level of effectiveness at a lower cost, the higher cost technology process option was eliminated on the basis of cost alone. Technologies that are eliminated on the basis of these criteria are identified in this section. The evaluation criteria are further defined below.

7.2.1 Effectiveness

The relative effectiveness evaluation of each technology process option considers its potential effectiveness and proven reliability in relation to the nature and extent of impact to the media to be addressed. The effectiveness evaluation also considers potential impacts to human health and the environment that might occur during the construction and implementation of the technology.

7.2.2 Implementability

The implementability evaluation addresses the technical and administrative feasibility of implementing a technology and the availability of various materials and services required during its implementation. Technical feasibility includes the consideration of the reliability, maturity, prior application, and operational difficulties of a technology as well as logistical, climate, and terrain limitations. Administrative feasibility includes the consideration of coordinating activities with regulatory agencies and obtaining permits, easements, right-of-way agreements, and zoning variances. In addition, the acceptance of a technology by regulatory agencies and the community is also an important component in considering the implementability of a process option.

7.2.3 Relative Cost

The cost criterion addresses the relative magnitude of capital and operation and maintenance (O&M) costs. Capital costs consist of direct and indirect costs. Direct costs include costs associated with construction, equipment, materials, transportation, disposal, analytical services, treatment, and operation. Indirect costs include expenses related to engineering, design, legal fees, permits, and start-up. O&M costs include costs associated with operation, maintenance, energy, residual disposal, monitoring, and support. Three cost ranges are used for purposes of this evaluation, as follows:

	Capital Costs	O&M (annual for at least 5 years)
Low	<$1 million	<$50,000
Moderate	$1 million - $5 million	$50,000 - $100,000
High	>$5 million	>$100,000

These ranges were made on the basis of engineering judgment and experience with projects of comparable scope and magnitude.

7.3 Technologies for Mitigating Soil Impacts

As summarized in Section 3.0, soil samples were collected and analyzed from the Site during the RI and several constituents were identified as COC. The final list of COC and their associated RGs in soil were developed in Section 6.0 and are summarized in Table 17. A number of technologies that could potentially mitigate impacts have been identified based on soil characteristics, the general nature of the COC, and the site conditions. A preliminary evaluation of these technologies is given below.

7.3.1 No Action

LDEQ Title 33, Part VI regulations require that the no action alternative be evaluated at every site to establish a baseline for comparison. Under this alternative, no response

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action of any kind would be employed. The no action alternative will not reduce the source of constituents in the soil as the Site or prevent the release or threat of release of these constituents to surface water or groundwater; therefore, this alternative is not more protective of human health and the environment than the current condition. The following summarizes the evaluation of this remedial technology with respect to the evaluation criteria.

Effectiveness:	Does not meet RAOs.
Implementability:	Readily implementable.
	Generally unacceptable to regulatory agencies and public.
Relative Cost:	Low.
Conclusion:	Does not meet the RAOs, but retained as a baseline for comparison with other technologies as required.

7.3.2 In Situ Containment (Stabilization)

In-place stabilization/containment technologies control potential hazards by eliminating routes of exposure and potentially reducing constituent migration through isolation and elimination of infiltration and groundwater flow through impacted soils. Although such technologies can significantly reduce or eliminate contaminant movement, they may or may not treat or reduce the mass of contaminants.

Based upon the various technologies available for stabilization, deep soil mixing (DSM) is most likely the technology with the best balance of performance, implementability, and cost. DSM utilizes continuous-flight, multiple augers in a series to stabilize the natural soils in situ through mixing with one or more injected reagents. The DSM reagents are determined through a pre-design treatability study. It is anticipated that reagents such as Portland cement, bentonite, or other common materials would be potentially applicable for the Site. These materials will mix and bind with the clayey subsurface material at the Site given proper mechanical stimulation. This process results in macro-encapsulate residual materials and soil particles. It also will result in reductions in any volatile chemicals as a result of mechanical stimulation. These volatiles are typically captured by a vapor collection system employed in the area around the augers at the land surface. This technology has been successfully applied at many other waste sites around the country.

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Effectiveness:

For most soil types, in situ stabilization can create a relatively uniform mass of very low permeability soil using stabilizing additives (e.g., Portland cement, cement kiln dust, etc.), essentially creating a block of material that prevents or mitigates movement of water and contaminants through or from this mass. As discussed above, it can also result in reductions in volatile chemicals as a result of mechanical stimulation and off-gas collection.

DSM has been used at many waste sites and has a wide range of application to different chemicals. These include metals, polyaromatic hydrocarbons (PAHs; for instance, coal tar and creosote), volatiles, pesticides, and others.

Implementability:

The DSM technique consists of mixing and stabilization using large augers that provide the mechanism for mixing. It requires an open area unimpeded by surface or subsurface infrastructure.

Bench scale testing must be conducted prior to implementation to identify the proper additives for the native soil and to demonstrate that performance goals (e.g., upper limit permeability values) are achievable.

An expected result of DSM is an increase (rise) in land elevation due to bulking factors. A typical increase in land elevation is 25 percent of the total depth of stabilization, but this varies with soil and additives type. This rise in surface elevation will alter the surrounding drainage patterns, and probably will impact neighboring properties.

In general, this technology is very implementable, well demonstrated, and reliable for many conditions.

Relative Cost:

- Moderate capital and low O&M costs.

Conclusion:

May be satisfactory for areas north and south of the railbed embankment, but not under the embankment itself. Probably not a stand-alone technology because it would not be feasible for the railbed area proper without removing the railbed and interrupting rail service. Will create offsite issues related to drainage. This will be evaluated further in the detailed evaluation of technologies.

7.3.3 In Situ Containment (Capping)

A capping system could be installed on the railbed and adjacent slopes to mitigate infiltration and increase runoff. Because there is a substantial grade to the embankment and the surface is uneven, a Resource Conservation and Recovery Act (RCRA)-type cap consisting of alternating impermeable and permeable layers is not considered feasible. However, a thin cap system might be feasible. Such a system would consist of an applied or sprayed on low-permeability barrier such as a geosynthetic clay liner (GCL) or GundSeal GCL. Unlike a multi-layer, engineered cap, this cap would utilize materials that could be designed to allow relatively easy, cost-effective installation around and under the rails themselves.

The following summarizes the evaluation of this remedial technology with respect to the evaluation criteria.

Effectiveness:

- Effective and compatible with current land use, but performance will degrade over time and require maintenance or replacement;
- Contains the mass of contaminants below the cap by preventing surface infiltration; will slow, but will not prevent, migration of COC to surface water and groundwater; and
- Probably not completely impermeable and not necessarily permanent; would need some maintenance and eventual replacement, doubling the installation cost after approximately 10 to 15 years.

Implementability:

- Easily implemented using well-proven surface applications; and

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- Should be acceptable to current property owner and should not disrupt operations during construction.

Relative Cost:

- Moderate capital and moderate O&M costs.

Conclusion:

A capping system may be satisfactory for the railbed and embankment. However, it is not a good stand-alone technology because it would not be particularly useful for the areas south and north of the embankment. In addition, the cap would eventually need extensive repairs or replacement. This technology will be evaluated further in the detailed evaluation of technologies.

7.3.4 In Situ Treatment (Chemical/Biological/Thermal)

In situ treatment of contaminants is a potentially effective means of treating many constituents and major advances in this area have been made over the last 10 years. Under favorable conditions, successful in situ treatment will destroy/degrade contaminants faster, more effectively, and less expensively than almost any conventional technology. However, the selection of the exact technology to be utilized, and the ability to distribute reagents and/or chemicals, is not straightforward and must be designed and implemented with great planning and care.

Three primary compounds have been observed at concentrations exceeding site closure criteria:

- Phenol - a highly water-soluble (82,800 mg/L) aromatic alcohol. Phenol is biodegradable (aerobically and anaerobically) and is susceptible to oxidants, including permanganate ion and hydroxyl radical (generated by Fenton's reagent). The boiling point of phenol is 181.7°C;

- Dicyclopentadiene - a two-ring compound that photo-decomposes in the atmosphere, is a solid at typical soil temperatures (melting point = 33.6°C), but is probably a liquid at the soil temperatures at the Eunice site. It is sparingly water soluble (20 mg/L at 20°C) and is not considered highly biodegradable. It is susceptible to permanganate oxidation (the Baeyer test for alkenes) and is expected to be readily oxidized by hydroxyl radical (kinetic rate constants were not available). The boiling point of dicyclopentadiene is 170°C; and

- 1,2-Dichloropropane - a water-soluble (2,800 mg/L at 20°C) chlorinated alkane that is expected to be resistant to permanganate oxidation and is only moderately susceptible to hydroxyl radical oxidation. 1,2-Dichloropropane is very susceptible to breakdown by microbes in a reducing environment (microbial reductive dechlorination). The boiling point of 1,2-dichloropropane is 96°C.

Focused research conducted on these compounds suggests that it may be feasible to treat all three compounds in situ, but a combination of two or even three different technologies will probably be required.

7.3.4.1 Chemical Oxidation

Effectiveness

In situ chemical oxidation using hydrogen peroxide and an iron sulfate solution (Fenton's reagent) is commonly used to oxidize petroleum hydrocarbons. The process involves injecting the solutions into the contaminated saturated zone. The solutions will react with petroleum hydrocarbons dissolved in the groundwater and adsorbed to the saturated soils.

Fenton's reagent is effective in the degradation of many environmental contaminants including chlorophenols, formaldehyde, benzene, toluene, ethylbenzene, and xylene (BTEX), polychlorinated biphenyls (PCBs), PAHs, dye process waste, and pesticides. The method is most effective in the treatment of compounds dissolved into the aqueous phase such as in wastewater and soil slurries.

Fenton's reagent consists of mixing an iron salt solution with hydrogen peroxide (H_2O_2) to generate hydroxyl radicals (OH^-). The OH^- radicals produced are highly reactive and will oxidize many environmental constituents. The reaction between hydrogen peroxide and iron occurs very rapidly and is extremely exothermic. This necessitates that the two components be mixed in the medium to be oxidized. Fenton's reagent is a very effective oxidizer when the impacted soil is permeable. Because Fenton's reagent is short-lived, distribution must be completed quickly. This presents challenges to the design of delivery systems in less permeable soils, but is not insurmountable. Additionally, Fenton's reagent requires the treatment area soil pH to be adjusted to 3 to 5 standard units prior to treatment.

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Hydroxyl radicals can also be created using a non-Fenton's reagent method. Using the commercial product Synergist, manufactured by En-Rx, hydrogen peroxide can be activated using a catalyst such as sodium. The Synergist product produces the same quantity of hydroxyl radical ions as Fenton's reagent, but does so over a much longer time period allowing for distribution through less permeable material while the oxidizer is still active.

Both of the technologies described above have been proven to be effective for treatment of the type of chemicals at this Site; however, their effectiveness is dependent on the ability to deliver the reagents through the impacted area for contact with the COC. Low permeability soils present the most challenging environment for delivery of remediation agents. Use in low permeability settings may require broad-area delivery systems such as trenching.

Focused research performed for this project suggests that a combination of in situ technologies could be effective in treatment of the COC. The two technologies, to be used in combination, are chemical oxidation and biological remediation. This possibility was evaluated through a technology evaluation study that was implemented to confirm this preliminary conclusion. This study, and the results thereof, is described in Section 7.4.

Implementability:

In situ treatment of contaminants in soil at this Site should be implementable but presents a challenge because of the lowland setting, low permeability subsurface soil, and the likelihood that more than one type of treatment may be necessary. A pilot study, utilizing hydrogen peroxide, was performed at the Site in 2004. Various concentrations of hydrogen peroxide were injected into the soil on the south side of the tracks by means of both a high-pressure lance and piezometers. The injection of peroxide alone did not successfully treat the chemicals.

The delivery mechanisms themselves (lances, piezometers, or trenches) are easily implemented but care must be taken to prevent the release of reagents, especially oxidants, to the environment. The use of the high-pressure lance appeared to allow the reagent to utilize cracks and fissures to by-pass significant areas of impact. The result of injection by means of piezometers was inconclusive. The use of trenches to deliver the reagent will be discussed in Section 7.4.

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Relative Cost:

Based on applications at other sites and taking into consideration the unique conditions at this site, it is likely that both the capital costs and O&M costs for a full-scale application of in situ technologies would be in the moderate range. Costs for O&M are mainly related to monitoring costs and would diminish after a few years if the technology is successful. The technology evaluation data will be used to better define site-specific costs.

Conclusion:

The use of an oxidizing reagent is feasible if it can be delivered to the COC. It may not be suitable for the railbed area proper unless it is feasible to get the reagent under the embankment. The technology evaluation data will aid in assessing this approach. This technology will be evaluated further in the detailed evaluation of technologies.

7.3.4.2 Biological (Enhanced Reductive Dechlorination)

Effectiveness

The goal of ERD is to furnish organic carbon to the subsurface environment so that indigenous microbial populations will flourish and remove available oxygen from the environment. This results in the formation of sequentially lower reduction-oxidation (redox) environments, with greater utilization of alternative electron acceptors, such as ferrous iron, manganese^{+2}, sulfate, and carbon dioxide, resulting in faster rates of reductive dechlorination (Lenzo 2000).

An advantage of ERD utilizing organic carbon substrates is the ability to directly treat mass that is adsorbed to the subsurface soil matrix. In general, any remedial technology for soil/groundwater is limited by the rate of desorption of COC mass to the dissolved phase. The ability of ERD technology to facilitate treatment of adsorbed mass is due to several factors:

- In a carbon-rich aqueous environment, hydrophobic constituents will tend to partition from the soil matrix into the aqueous environment;
- A flourishing microbial community produces natural surfactants (consisting of carbohydrates and lipids) which aid in desorbing mass from the soil matrix; and

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- Fermentative conditions created in the subsurface via ERD produce low concentrations of alcohols which can have a co-solvency effect, making mass accessible to the microbial population for treatment.

The composition of microbial communities shifts continually in response to the dissolved organic matter supply and the availability of essential nutrients. An important factor in microbial community structure is the nature of chemicals available in the environment that serve as terminal electron acceptors in the microbial respiratory pathway. Oxygen is the dominant terminal electron acceptor in natural systems and respiratory processes that utilize oxygen as the terminal electron acceptor are termed aerobic.

In some natural habitats, such as lake and river sediments, dissolved organic matter supplies are plentiful, but the availability of oxygen is low. In these cases, the composition of microbial communities shifts toward species that utilize alternative electron acceptors such as nitrates, reduced metal ions (Fe^{2+}, for example), and sulfates. These anaerobic habitats reach very low redox potentials, occasionally below -400 millivolts (mV). The microbial communities that thrive under the most reducing communities utilize sulfates and carbon as terminal electron acceptors, generating sulfides, elemental sulfur, carbon dioxide, and methane as by-products. These communities are termed sulfate reducers and methanogens. This environment is where reductive dechlorination occurs.

Enhanced reductive dechlorination is induced by the injection of rapidly degradable organic carbon into a contaminated environment thereby intentionally shifting the environment toward anaerobic conditions. Molasses, milk whey, and high-fructose corn syrup are commonly available carbon-rich materials that can be used to stimulate reductive dechlorination. Reductive dechlorination can be achieved through two different routes: cometabolic degradation by sulfate reducing and methanogenic communities present in the system, and metabolic degradation by a class of bacteria termed "dehalorespirers". Sulfate reducing and methanogenic microbial communities produce enzymes that reduce chlorinated solvent molecules, but they gain no energy from this process. Conversely, chlorinated compounds serve as electron acceptors in the metabolic processes of dehalorespiring bacteria. These bacteria receive energy from the compound and only require a carbon and electron source in order to complete the degradation process. Dehalorespirers thrive in sulfate reducing and methanogenic conditions.

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Both the cometabolic and metabolic degradation of chlorinated compounds will be supported in sulfate reducing and methanogenic conditions. These conditions will be maintained in the technology evaluation test area through periodic additions of carbohydrate reagent, which will be sustained until satisfactory chlorinated compound reduction has been achieved.

Implementability:

In situ treatment of contaminants in soil at this Site is implementable but conditions do present a challenge because of the lowland setting, the low permeability of subsurface soil, and the low concentration remedial goals. Multiple delivery systems may be necessary to achieve delivery of the high carbon material to the required depths.

Relative Cost:

Based on applications at other sites and taking into consideration the unique conditions at this Site, it is likely that the capital costs for a full-scale application of in situ technologies would be in the moderate range. Costs for O&M are low to moderate depending upon the technology utilized for the railbed area. The technology evaluation test data will be used to better define site-specific costs.

Conclusion:

The use of ERD is feasible if it can be delivered to the COC. It will present a challenge for the railbed area proper to develop a delivery mechanism to get the carbon substrate under the embankment. The technology evaluation test data will aid in assessing this approach. This technology will be evaluated further in the detailed evaluation of technologies.

7.3.4.3 *In Situ Thermal Treatment*

The primary application of in situ thermal treatment uses heater wells, along with vapor extraction wells, which can be placed to virtually any depth in virtually any media. Heat is applied to soil from a high-temperature surface in contact with the soil, so that radiation and thermal conduction heat transfer are effective near the heater. As a result, thermal conduction and convection occur in the bulk of the soil volume. Overall, thermal conduction accounts for over 80 percent of the heat transfer. A significant feature of the in situ thermal treatment process is the creation of a zone of very high

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temperature (>1000 degrees Fahrenheit) near the heaters, which can oxidize or pyrolize contaminants. A soil vapor extraction system is used to remove contaminants.

In situ thermal treatment can treat organic contaminants, including free product in the form of light non-aqueous phase liquids (LNAPLs) or dense non-aqueous phase liquids (DNAPLs). It possesses high removal efficiency because it does not rely on injection of fluids to mobilize target compounds. In situ thermal treatment is based on thermal conduction through the soil, providing a uniform heat transfer. It is applicable in tight soils, clay layers, or in soils with wide heterogeneity in permeability or moisture content.

In situ thermal treatment has been proven to be an effective treatment for soils contaminated with certain constituents, mainly a broad range of organic chemicals. The development of this technology has progressed significantly in the last 10 years and, considering the nature of contaminants at the Eunice site, it may have some applicability.

Effectiveness:

In addition to being quite effective for a broad range of organic chemicals in soil, a distinct advantage of in situ thermal treatment is that it is not hindered by the permeability of the soil and thus does not have the distribution problem that chemical and biological technologies may have. In some cases, the presence of large amounts of groundwater can adversely affect the technology because this water may have to be boiled off in order to reach desired temperatures. The clayey nature of soil at the Eunice site does not seem to present this limitation.

The effectiveness of treatment of each of the contaminants to the stipulated RECAP target concentrations would be feasible by attaining the boiling point of water (100°C) throughout the target treatment zone (TTZ) and boiling off a fraction of the pore water. It does not appear that it would not be necessary to achieve temperatures above the boiling point of water, as is the case with higher boiling compounds such as PCBs, PAHs, and pesticides. This preliminary judgment could be confirmed through performance of an inexpensive bench scale thermal treatability test.

Implementability:

During system operation, heat is injected into the soil by thermal conduction from the heater/vacuum wells. The heat radiates away from the wells while vaporized

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components are drawn back toward the well by applied suction in a counter current fashion. The heater/vacuum wells are connected through piping to the off-gas treatment process system. The degree of implementability is site specific. Remote sites would require large generators to deliver electricity to the heater wells. Buried infrastructure (electric, gas, etc.) can present problems. However, angled drilling, etc., can allow it to be applied under roads, foundations, and other fixed structures that ordinarily could not be treated.

Additionally, there can be some concern over gaseous products that could be generated from the in situ thermal process. Although gases are primarily CO_2 and H_2O, HCl is a decomposition product from the degradation of chlorinated solvents. Monitoring of the amounts of HCl in the off-gas may be used to monitor the progress of remediation. In addition to monitoring HCl, the temperature is monitored in the coolest regions of the heated area.

Finally, there may some concern over changes in soil strength and/or stability as a result of thermal treatment, particularly if high temperatures are required. There may also be an impact on the fiber optic cables that run along the north side of the railbed. This would also need to be evaluated in the pre-design phase of bench scale testing.

Relative Cost:

In general, in situ thermal treatment is a high-cost technology (e.g., in the range of \$100 to \$250 per cubic yard [cy]); however, it does avoid excavation and handling costs and it eliminates disposal costs. It may also avoid the expense of interrupting rail service during remediation.

Conclusion:

This technology is retained for further consideration because it is probably effective if the impacts to other areas of the infrastructure can be resolved. It is considered cost prohibitive to be used for the entire site, but it may be practical to use under the tracks and embankment where other technologies would be difficult or very expensive.

7.3.5 Removal and Treatment/Disposal

The potentially applicable technology for removal of contaminated soil is excavation. Areas of COC exceeding the RGs would be removed, and the excavated materials would be treated and/or disposed of off site. Subsurface soil sampling results as discussed in Section 3.0 indicate that soil at the Site is impacted to varying depths that range from a few feet down to a maximum of 42 ft bls. The impacted area is approximately 60,000 square feet. If all horizontal areas, including the railbed, are included in the excavation, the expected volume for removal would be about 77,500 cy.

Due to unique environmental and hydraulic conditions at the Site, it is anticipated that several different excavation techniques would potentially be utilized. This includes traditional trackhoe excavation north of the railbed, although shoring may be required between this area and the railbed embankment to prevent failure of the railbed into the excavation and possible removal using oversized augers south of the railbed. This will be necessary because of the proximity to and hydraulic head in the Eunice City Lake.

Due to the presence of acrylic acid and/or toluene diisocyanate in the material to be excavated, the likely means of treatment is off-site incineration, unless LDEQ grants the variance request for treatment of acrylic acid. Incineration of contaminated soil requires characterization and transportation to a facility that is permitted to accept the specific waste. The following summarizes the evaluation of this remedial technology with respect to the evaluation criteria.

<u>Effectiveness</u>:

Assuming excavation can reach/address all impacted areas, this technology should be effective in reducing the volume and mobility of contaminants on site.

Removal and treatment/disposal is a proven technology for COC because all impacted soil above RGs would be removed and disposed of at an appropriately permitted site.

<u>Implementability</u>:

- Will create exposure to contaminants during construction, although this can be minimized with appropriate engineering controls, such as dust suppression, and evaluated through direct air monitoring;
- Difficult to implement given lowland conditions and the current land use; would significantly disrupt (i.e., stop) railroad operations for several months; and
- Transportation of hazardous waste by truck through residential streets may create objections by the community due to noise and the nature of the cargo.

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Relative Cost:

- High capital and low O&M costs.

Conclusion:

Removal and treatment/disposal should be effective if implementable, although at a very high cost. This technology is retained for the detailed evaluation of technologies.

7.4 Technology Evaluation

7.4.1 Introduction

Previous field testing at the Site using permanganate oxidation has shown some promise but has not shown complete destruction of all target compounds. This section discusses the target compounds and the chemistry of the compounds and provides an introduction to two suggested technologies for destroying the compounds, the methodology used in the technology evaluation, and a discussion of the results.

Three primary compounds have been identified as the major COC at the Site as discussed in Section 7.3.4.

7.4.2 Site Hydrogeochemistry

The hydrogeochemistry and the contaminant mass distribution at the Site play an important role in choosing the appropriate remediation technology. These parameters include the soil chemistry, which at the Site is composed of granitic ballast in the upper section of the railbed, which would be low in carbonate alkalinity and had a pH of 6.6 standard units (s.u.) during initial testing. The lower portion of the railbed is composed of alluvial soil with shell road base. This material is high in carbonate alkalinity and had a measured pH of greater than 8 s.u. in initial testing.

The railbed is perched above the surrounding ground surface and is therefore minimally influenced by the steady-state groundwater table. Initial testing indicates that the hydraulic conductivity of the railbed and immediately adjacent material is relatively low. While it is possible to flood the material and maintain saturation, the ability to hydraulically drive solution through the area is considered minimal.

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7.4.3 Proposed Remediation Technologies

Several in situ technologies should be considered for treatment of impacted soil in place as discussed below. The most likely candidates for success include oxidation technologies and ERD.

7.4.3.1 Chemical Oxidation

Chemical oxidation is a direct contact technology in which partial to complete destruction of the compound is achieved via removal of electrons from the compound using a strong oxidant. In choosing an appropriate oxidant several factors should be considered. First, the oxidant must deliver enough chemical energy to break the chemical bonds in the target compound, and second, the reaction must occur fast enough so that the oxidant is not consumed by competing reactions with surrounding material.

For chemical oxidation to be successful, the oxidant must be brought into direct contact with the target compound. Therefore, delivery of the oxidant as a function of hydraulic conductivity is important. Because this Site has a relatively low hydraulic conductivity it is important to choose an oxidant that has a moderate "life-span" so that it can reach the target compounds once delivered.

7.4.3.2 Enhanced Reductive Dechlorination

ERD is an in situ bioremediation technique that increases mass removal rates by stimulating enhanced rates of biological degradation through manipulating the groundwater environment through addition of an organic carbon substrate. ERD is appropriate for chlorinated compounds and many heavy metals.

The ERD technology, developed by ARCADIS, is covered under Patent #6,143,177 and has been successfully applied at many sites across the United States. It involves the introduction of organic carbon in the form of molasses, corn syrup, or similar carbohydrate into the impacted area. The indigenous microbial population will utilize the organic carbon as a food source and exhaust naturally occurring electron acceptors such as dissolved oxygen, nitrate, ferric iron, and sulfate. This creates reducing conditions which are conducive to the biological degradation of chlorinated compounds such as 1,2-dichloropropane.

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7.4.3.3 Approach and Methodology

In May 2005, ARCADIS performed a technology evaluation on both the north and south sides of the railroad track at the Site to evaluate two different technologies. ERD and chemical oxidation (hydroxyl ion oxidation) were both evaluated at the Site to degrade the target compounds. Chemical oxidation was used in the area north of the track, which is impacted with all three primary COC: phenol, dicyclopentadiene, and 1,2-dichloropropane. Two of the three compounds are amenable to chemical oxidation as discussed earlier, providing adequate delivery and distribution of the oxidizing agent can be achieved in the low permeability soil. ERD was evaluated in the area south of the track, which is primarily impacted with 1,2-dichloropropane.

Because both chemical oxidation and ERD technologies are dependent on the ability to deliver the reagents to the impacted area and low permeability soils like those at the Site present the most challenging environment for delivery of remediation agents, an effective delivery system had to be designed. For this project, a trench delivery system was used.

Using this approach, excavated trenches were installed and immediately backfilled with high permeability gravel. For the chemical oxidation evaluation north of the track, the evaluation included three trenches approximately 15 feet deep, spaced 10 feet apart and 90 feet long through the impacted area. For the ERD evaluation south of the track, a smaller test area was used. This was comprised of two trenches, approximately 15 feet deep, spaced 10 feet apart and 20 feet long. A graphical depiction of the area and the trenches is shown on Figure 10. Due to soil consolidation problems and sloughing, the width of the trenches at the surface was often larger than designed and greater than the width at the base of the trench.

The excavated soil removed during the trenching was used to construct embankments around the treatment areas. Prior to backfilling the trenches with gravel, a 4-inch diameter Schedule 40 PVC perforated pipe was place horizontally in the base of each trench. The terminal ends of the pipe were fitted with 90-degree connectors and solid pipe which extended to the surface and above grade for the delivery of the reagents into the trench. Each trench was also equipped with a 1-inch diameter piezometer to allow the measurement of fluid level in each trench.

Prior to the installation of the trenches, a baseline soil sampling event was performed at the Site. The locations north of the track were designated as "ChemOx-1" through "ChemOx-8". Sample location identifiers that were resampled over time contain a

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suffix of "A", "B", or "C" to designate the first, second, or third sampling event, respectively. Four of the eight locations were sampled on three occasions: baseline; day 30; and day 60. The remaining four locations were sampled only on day 60 to better delineate the effect of the chemical oxidant treatment to do possible displacement of the soil mass due to trenching. A graphical depiction of the soil sample locations for the north side of the track is shown in Figure 11. Two soil sample locations were used on the south side of the track. These locations, designated as "IRZ-1" and "IRZ-2", also contain the suffix "A", "B", and "C" in reference to the sampling event of baseline; day 30; and day 60. A graphical depiction of these soil sampling locations is shown on Figure 12.

ARCADIS mobilized to the Site on May 9, 2005, with Eagle Construction, a direct subcontractor to Union Pacific, for the installation of the trenches. All excavation work was completed by May 17, 2005. Chemical oxidation treatment on the north side of the track was performed first. The chemical oxidant used, hydroxyl radical, was generated using a novel reaction of the commercially available product known as Synergist-D, manufactured by EN-RX, Inc., of Houston, Texas. This agent, similar to the Fenton's reagent, produces hydroxyl radical through the interaction of 35 percent hydrogen peroxide solution with a transition metal. In the typical Fenton's reagent reaction, this is accomplished by using ferrous iron as the transition metal. This reaction is highly energetic and short-lived and therefore delivery of the resulting hydroxyl radical solution must be done quickly to achieve contact with the target compounds.

ARCADIS chose to use the Synergist-D compound to generate the hydroxyl radical for this project because it uses a carbonate coated sodium catalyst to generate the hydroxyl radical. This reaction produces the same quantity of hydroxyl radical as the Fenton's Reagent reaction but does so at a slower and more controlled rate, up to 60 days. This allows the reagent to be delivered to the impacted area and contact made with the target compound prior to the reaction producing the full energy yield. Preliminary data provided by the Synergist-D vendor showed very promising results and hydroxyl radical production extending beyond 60 days at some sites. Thus the agent was chosen as a good candidate for this technology evaluation.

Reagent activation and delivery at the Site were performed on May 18, 2005. A chemical mixing and staging area was set up approximately 1,600 feet east of the Site at the terminal end of the existing 6-inch diameter high-density polyethylene (HDPE) piping run. This area has historically been known as the "turnaround" in reference to the project. A 5,000-gallon HDPE tank was staged at this area with pumps connecting a 35 percent hydrogen peroxide tanker to a 5,000-gallon potable water storage tank. A

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connection was made to the existing 6-inch diameter HDPE pipe that runs to the north side of the track so it could be used as a chemical delivery conduit. The proximal end of the piping run was piped to a connector that could secured to the piping in each of the three trenches. This design allowed metering of reagent into each trench separately and gauging of the fluid levels via the trench piezometers. The constructed embankment provided containment of reagent to the treatment area.

Several batch applications of reagent were mixed and delivered to the trench system from May 18, 2005, until May 21, 2005. In general, the batch consisted of 1,100 gallons of 35 percent hydrogen peroxide, 250 pounds of dry Synergist-D catalyst, and 1,900 gallons of water. The components were added to the mixing tank and recirculated for 1 hour to ensure complete mixing. The activated reagent was then pumped down the 6-inch HDPE pipe and into the trench while the fluid levels were monitored in the trench and the fluid delivery was metered from the tank. In general, 3,000 gallons were delivered in each batch, which filled each trench to approximately 95 percent capacity. Upon delivery of reagent to all three trenches, additional reagent was pumped into the embankment area to flood the surface soils and the impacted soil used to create the embankment. This also allowed for the creation of hydraulic head which provided downward gravity drive to force the reagent deeper into the treatment area. The bermed area was filled to approximately 2 feet above grade and completely infiltrated into the treatment area within 30 minutes. In order to further drive the reagent into the treatment area, the embankment was filled with potable water to approximately 2 feet above grade. This was repeated twice as the water level subsided. In general, infiltration of the potable water took 8 to 12 hours, indicating saturation of the pore spaces in the treatment area. ARCADIS provided 24-hour surveillance of the treatment area until all standing fluid had infiltrated.

The observed reaction of the hydroxyl radical with the impacted soil was moderately energetic. Steam and heat were observed from the trenches. Air monitoring of phenol using Draeger tubes was performed during the stage of the treatment to determine if volatilization was occurring. No measurable concentrations were detected in the breathing zone.

On May 21, 2005, the ERD treatment on the south side of the track was begun. A 44,500-pound (5,500-gallon) shipment of 2 percent feed-grade molasses was delivered to the Site from Westway Feed Products in Houston, Texas, via tanker truck. The solution was discharged into the two trenches on the south side of the track equally which brought the fluid level to approximately 85 percent of capacity. The trenches were then filled with approximately 200 gallons of potable water and the surface appurtenances sealed to the atmosphere. The adjacent bermed area, as shown on Figure 10, was filled with impacted soil during the excavation of the trenches. This soil was treated via chemical oxidation by applying a concentrated mixture of activated Synergist-D reagent to the soil and performing comprehensive surface mixing with a diesel-powered excavator.

7.4.3.4 Results

As discussed earlier, baseline soil sampling was performed on both the north and south sides of the track prior to installation of the treatment trenches. Sampling was performed using direct push technology with discrete soil samples collected at intervals historically known to be impacted. In general, these intervals corresponded to 8 to 10 ft bls, 12 to 14 ft bls and 14 to 16 ft bls on the north side of the track. The uppermost interval of 8 to 10 ft bls was chosen due to a soil excavation performed on the north side of the track in 2000 that removed native soil to a depth of approximately 10 ft bls.

Baseline soil sampling on the south side of the track was also performed with discrete samples being collected from 2 to 4 ft bls, 10 to 12 ft bls, and 18 to 20 ft bls. Baseline soil sample results for both the north and south areas are presented in Table 18 and graphically depicted on Figure 13 (north side) and Figure 14 (south side).

On the north side of the track, the maximum reported concentrations for the target compounds are shown in the table below:

Interval	Constituent	Concentration (mg/kg)
8-10 ft bls	1,2-dichloropropane	188
	Dicyclopentadiene	<0.077
	Phenol	82.2
12-14 ft bls	1,2-dichloropropane	342
	Dicyclopentadiene	0.127
	Phenol	416
14-16 ft bls	1,2-dichloropropane	394
	Dicyclopentadiene	0.08
	Phenol	68.5

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On the south side of the track, the maximum reported concentrations for the target compounds are shown in the table below.

Interval	Constituent	Concentration (mg/kg)
2-4 ft bls	1,2-dichloropropane	4,700
	Dicyclopentadiene	<0.077
	Phenol	15.6
8-10 ft bls	1,2-dichloropropane	810
	Dicyclopentadiene	<0.077
	Phenol	11.6
18-20 ft bls	1,2-dichloropropane	9.11
	Dicyclopentadiene	<0.077
	Phenol	<0.03

Two follow-up soil sampling events were performed at 30 and 60 days after treatment. On the north side of the track the same locations (3-foot offset) as the baseline event were repeated on day 30 and relocated to four new locations for the day 60 sampling for the purpose of further delineating the treatment area. On the south side of the track, the two sampling locations were repeated with a 3-foot offset, on day 30 and day 60. The results of the 30-day sampling event are presented in Table 19 and graphically depicted on Figure 15 (north side) and Figure 16 (south side). The results of the 60-day sampling event are presented in Table 20 and graphically depicted on Figure 17 (north side) and Figure 18 (south side).

7.4.3.5 Discussion and Conclusion

A comparison of baseline concentrations of the target compounds with the 30-day concentrations indicates that the majority of the target compounds were reduced in concentration. A small portion of the samples indicates a modest increase in concentration of some compounds. This is indicative of environmental variability in sampling of soil and can result in both positive and negative error. Therefore, it is more realistic to look at the results as a macroscopic view of the concentration range for the area rather than single points.

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For the four repeated (baseline and 30-day) sample locations on the north side of the track, the following percent reductions in target compounds were observed as a function of depth interval:

Sample Location	Sample Depth (ft bls)	Chemical Constituent	Baseline Concentration (mg/kg)	30-Day Concentration (mg/kg)	Percent Reduction (%)
ChemOx-1	8-10	1,2-DCP	1.46	0.079	95
		DCPD	<0.077	<0.024	ND
		Phenol	<0.038	0.94	+
	12-14	1,2-DCP	2.01	0.047	98
		DCPD	0.127	<0.024	84
		Phenol	<0.038	<0.038	ND
	14-16	1,2-DCP	2.3	1.6	30
		DCPD	0.0816	<0.024	75
		Phenol	<0.038	<0.038	ND
ChemOx-2	8-10	1,2-DCP	46.5	8.32	82
		DCPD	<0.077	<0.024	ND
		Phenol	5.20	<0.038	99
	12-14	1,2-DCP	342	208	31
ChemOx-2		DCPD	<0.077	<0.024	ND
		Phenol	416	19.3	94
	14-16	1,2-DCP	394	358	9
		DCPD	<0.077	<0.024	ND
		Phenol	1.46	1.88	+
ChemOx-3	8-10	1,2-DCP	54.9	60.4	+
		DCPD	<0.077	<0.024	ND
		Phenol	14	96.7	+
	12-14	1,2-DCP	152	60.6	60
		DCPD	<0.077	0.085	+
		Phenol	273	39.5	86
	14-16	1,2-DCP	215	60.9	72
		DCPD	<0.077	<0.024	ND
		Phenol	68.5	7.52	89

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Sample Location	Sample Depth (ft bls)	Chemical Constituent	Baseline Concentration (mg/kg)	30-Day Concentration (mg/kg)	Percent Reduction (%)
ChemOx-4	8-10	1,2-DCP	188	32	83
		DCPD	<0.077	<0.024	ND
		Phenol	82.2	7.21	91
	12-14	1,2-DCP	156	65.5	58
		DCPD	<0.077	<0.024	ND
		Phenol	32.2	18.6	42
	14-16	1,2-DCP	140	15.8	89
		DCPD	<0.077	0.093	ND
		Phenol	31.9	0.972	97

+ = Increase
ft bls = feet below land surface
mg/kg = milligrams per kilogram
1,2-DCP = 1,2-Dichloropropane
DCPD = Dicyclopentadiene
ND = Not Detected

For the two repeated (baseline and 60-day) sample locations on the south side of the track, the following percent reductions in target compounds were observed as a function of depth interval:

Sample Location	Sample Depth (ft bls)	Chemical Constituent	Baseline Concentration (mg/kg)	60-Day Concentration (mg/kg)	Percent Reduction (%)
IRZ-1	2-4	1,2-DCP	0.003	0.003	NC
		DCPD	<0.077	<0.024	ND
		Phenol	<0.038	<0.038	ND
	8-10	1,2-DCP	0.475	0.003	99
		DCPD	<0.077	<0.024	ND
		Phenol	<0.038	<0.038	ND
	18-20	1,2-DCP	0.787	4.21	+
		DCPD	<0.077	<0.024	ND
		Phenol	<0.038	<0.038	ND
IRZ-2	2-4	1,2 DCP	4700	0.03	99
		DCPD	<0.077	<0.024	ND
		Phenol	15.6	<0.038	99
	10-12	1,2 DCP	810	0.003	99

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Sample Location	Sample Depth (ft bls)	Chemical Constituent	Baseline Concentration (mg/kg)	60-Day Concentration (mg/kg)	Percent Reduction (%)
		DCPD	<0.077	<0.024	ND
		Phenol	11.6	<0.038	99
	18-20	1,2 DCP	9.11	0.605	99
		DCPD	<0.077	<0.024	ND
		Phenol	<0.038	<0.038	ND

+ =	Increase	NC =	No change
ft bls =	feet below land surface	1,2 DCP =	1,2-Dichloropropane
mg/kg =	milligrams per kilogram	DCPD =	Dicyclopentadiene
		ND =	Not Detected

It should be noted that there was an offset of approximately 5 feet between the baseline sampling event and the 30- and 60-day samples on the south side of the track. This was related to sloughing of the side walls into the trench area during construction. Therefore, post treatment samples were not collected in the same spot as the baseline samples.

In conclusion, the chemical oxidation of the target COC at the Site appear to have been successfully accomplished by the evaluated technology discussed above. This is not conclusive, as discussed above, and needs to be further evaluated. While this evaluation only applied a single application of oxidant and organic carbon a significant amount of compound destruction appears to have been achieved. A post-treatment delineation of the compounds is warranted with additional treatment required if needed. It is likely that a more comprehensive reductive dechlorination treatment will be needed on the south side of the track to fully degrade the target compounds at depth. However, the results to date, and extensive literature research, indicate that this technology can be successfully utilized at the Site, applicable delivery mechanisms can be designed and implemented, and this technology will provide a cost effective alternative to significantly reduce or eliminate on-site impacts while minimizing off-site impacts.

8.0 Identification and Detailed Analysis of Remedial Alternatives

The most applicable soil technology process options retained after the screening evaluation conducted in Section 7.0 are assembled into remedial alternatives and further evaluated in the following subsections. This section identifies the alternatives, describes the evaluation criteria, and further details the manner in which each retained technology process option comprising each alternative would potentially be

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implemented at the Site. Each alternative is then individually evaluated by the process described in LAC 33:VI.509.C.4. This section identifies seven criteria that must be considered in evaluating and comparing the acceptability of various identified alternatives.

8.1 Identification of Remedial Alternatives

The following remedial alternatives were developed to address the impacted soil at the Site. These were assembled from the technology process options deemed potentially applicable and retained for further consideration based upon the screening evaluation presented in Section 7.0.

With the exception of the No Action alternative, which must be carried through for comparison, the remaining alternatives were selected based on their ability to address each of the RAOs identified in Table 17. The medium and RAO addressed by each technology process option within each of the following alternatives is shown in Table 21. The alternatives are:

- Alternative 1 - No Action;
- Alternative 2 - In Situ Stabilization/Thin Cap System;
- Alternative 3 - In Situ Chemical/Biological Treatment and Thin Cap System;
- Alternative 4A - Removal, Capping, and Treatment/Disposal;
- Alternative 4B - Removal and Thermal Treatment;
- Alternative 4C - Removal and Treatment/Disposal;
- Alternative 5 - In Situ Thermal Treatment;
- Alternative 6A - Excavation and ERD Combination;
- Alternative 6B - Limited Embankment Excavation and ERD Combination; and
- Alternative 6C - Embankment Excavation and ERD Combination.

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8.2 Evaluation Criteria

The purpose of the detailed analysis is to objectively evaluate the remedial alternatives with respect to the required seven criteria.

The evaluation criteria consist of the following:

- Ability of the alternative to achieve the preliminary RS and other applicable requirements (i.e., effectiveness);
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability;
- Relative cost effectiveness; and
- Compliance with state and federal ARARs.

The following is an overview of each of the seven criteria required in the regulatory requirements:

- Ability of the alternative to achieve the preliminary RS and other applicable requirements.

  This criterion addresses how the remedial alternative achieves RS and how and whether it protects human health and the environment over time. Protection of human health and the environment is met if each human health and ecological exposure pathway identified in the risk assessment as potentially resulting in adverse effects is eliminated, reduced to an acceptable level (e.g., the RS), or controlled through treatment or engineering and institutional controls. The degree of restrictions on the use of the Site after remediation is also considered under this criterion.

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- Long-term effectiveness and permanence

  The long-term effectiveness criterion addresses how well the remedial alternative continues to protect human health and the environment in terms of the residual risk remaining at the Site after the remedial objectives have been met. This criterion considers the residuals following completion of the actions, expected duration of the remedy, and the degree of controls required to ensure protectiveness of the remedy.

- Reduction of toxicity, mobility, and volume

  This criterion relates to the extent to which remedial alternatives permanently reduce the toxicity, mobility, and volume of contaminants present at the Site. Factors for this criterion include the degree of permanence of the remedial action, the amount of hazardous materials destroyed, and the type and quantity of residuals remaining after treatment.

- Short-term effectiveness

  Short-term effectiveness addresses the effects of the remedial alternative during construction and implementation until the response objectives are met. This criterion considers the protection of the community and workers, including the air-quality effects and hazards from excavation, transportation, and on-site treatment. In addition, the expected length of time for completion of the remedial action is considered.

- Implementability

  The technical and administrative feasibility of implementing each remedial alternative and the availability of services and materials are addressed by this criterion. This criterion also considers the degree of coordination required by the regulatory agencies, successful implementation of the remedial action at similar sites, and research to realistically predict its field implementability.

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- Relative Cost

  This criterion addresses the capital costs, the operation and maintenance costs, and the present worth analysis of costs. The capital costs are divided into direct costs (construction) and indirect costs (non-construction and overhead). Direct capital costs include construction, equipment, land and site development, relocation, and disposal costs. Indirect capital costs include engineering expenses, legal fees, license or permit costs, start-up costs, and contingency allowances. Operation and maintenance costs consist of costs associated with post construction activities necessary to properly operate, maintain, and monitor a given remedy.

  The cost estimates presented in this CAS were developed based on Means Cost Data, vendor quotations, and previous project costs. The cost estimates in this report are thought to be within an accuracy range of +30 to -25 percent.

- Compliance with state and federal ARARS

  This criterion addresses whether the remedial alternative complies with applicable or relevant and appropriate federal, state, and municipal chemical-specific, action-specific, and location-specific requirements. For ARARs which are not met by an alternative, a waiver may be appropriate.

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8.3 Individual Analysis of Remedial Alternatives

The individual analysis of remedial alternatives in relation to the criteria outlined above is given in the following paragraphs. Results of the analysis are summarized in Table 22. In addition, as required by LDEQ, an estimate is provided of the time required to achieve the remedial standards for each alternative.

8.3.1 Alternative 1 - No Action

8.3.1.1 Description of Application

Under this alternative, no active remedy would be put in place. Regardless of the unlikeliness of this option, the no action alternative must be evaluated at every site to establish a baseline for comparison in accordance with LAC 33.VI.509.C.1.

8.3.1.2 Assessment

Although easily implemented, the no action alternative at the Site will not manage exposure to subsurface soils. Additionally, it will not provide a definitive means of source control or a means to mitigate possible impacts to groundwater.

8.3.1.3 Time to Achieve Compliance

The remedial standard will only be achieved under this alternative when the COC concentrations meet the standard by means of dispersion, dilution, or biodegradation. The timing of these processes is difficult to predict, but will likely take decades to meet the remedial standards.

8.3.2 Alternative 2 - In Situ Stabilization/Thin Cap System

8.3.2.1 Description of Application

In this alternative, impacted soil north and south of the elevated railbed would be stabilized in situ using oversized augers to physically mix and contain impacted subsurface soil in place. It would not be practical to use this technology below the railbed proper and the embankment without taking out the railbed itself. The volume of soil to be contained/treated using stabilization would be approximately 61,000 cy. Schematics showing the location of stabilization are given on Figures 19 and 20.

The augers would be turned to the depth of impacted soil at each particular location (estimated to vary from approximately 20 to 45 feet maximum). The exact depth will be determined using existing data and new data gathered during implementation. Auger holes would overlap so as to ensure complete encapsulation/treatment.

A thin cap system would also be designed and implemented as part of this scenario. This cap would cover the embankment and extend under the railbed. The main purpose of such a cap system would be to prevent precipitation from entering the vadose zone under the railbed and embankment area. This would encapsulate impacted subsurface soil and mitigate the mobility of contaminants. Such a thin cap system could consist of an applied or sprayed on low-permeability barrier such as Gunite or asphalt or a GCL or GundSeal GCL. Unlike a multi-layer, engineered cap, this cap would utilize materials that could be designed to allow relatively easy, cost-effective installation.

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8.3.2.2 Assessment

Based on experience with this technology at other locations, it should be possible to create a monolithic mass of low permeability material (i.e., 10^{-6} cm/sec or less) that also eliminates potential zones of preferred groundwater flow (e.g., sand lenses). The mass would have a high degree of strength and therefore would have no adverse effect on the railbed. The land surface would rise from a few feet up to 10 feet, depending on the depth of the auger hole, due to the bulking factor. Due to the already fine-grained nature of the soil at the Site, relatively modest levels of additives would likely be necessary to stabilize the impacted soil. Bench scale testing would be necessary to determine the optimal additives and required amounts. The area to be capped is an estimated 13,500 square feet. The thin cap will need to be replaced at regular intervals of approximately every 10 years.

8.3.2.3 Time to Achieve Compliance

Assuming 28 work days to contract and mobilize to the Site, 30 days to construct access to the Site from the north side, 14 days for a bench scale test, an average of two holes per day on the south side and four holes per day on the north side, plus 16 days to apply the Gunite or equivalent barrier and 5 days to dress the Site and demobilize, the total number of work days required to implement this technology would be 349 working days or 506 calendar days. This technology will contain the COC, but will not achieve the remedial standards.

8.3.3 Alternative 3 - In Situ Chemical/Biological Treatment and Thin Cap System

Several in situ technologies will be considered for treatment of impacted soil in place. The most likely candidates for success include oxidation technologies and ERD. ERD is an in situ bioremediation technique that increases mass removal rates by stimulating enhanced rates of biological degradation through manipulating the groundwater environment by adding an organic carbon substrate. The following section describes this approach and presents a conceptual scope proposed for the Site. Figures 21 and 22 provide schematics for this alternative.

8.3.3.1 Description of Application

ERD and chemical oxidation (hydroxyl ion oxidation) were evaluated at the Site to degrade the target compounds (see Section 7.4). Chemical oxidation was used in the area north of the track, which is impacted with all three primary COC: phenol, dicyclopentadiene, and 1,2-dichloropropane. Two of the three compounds are

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amenable to chemical oxidation providing adequate delivery and distribution of the oxidizing agent can be achieved in the low permeability soil. Because of the uncertainty over the ability to achieve the desired results for these contaminants in this particular setting, two comprehensive technology evaluations were performed as described in Section 7.4.

Both chemical oxidation and ERD technologies are dependent on the ability to deliver the reagents through the impacted area for contact with the COC. Low permeability soils present the most challenging environment for delivery of remediation agents. For this project, ARCADIS used a trench delivery system. Using this approach, 3-foot wide excavated trenches were installed and immediately backfilled with high permeability gravel. For the chemical oxidation evaluation north of the track, the evaluation included three trenches approximately 10 feet deep, spaced 10 feet apart for the full 100 feet of the impacted area. The excavated soil removed during the trenching was used to construct berms around the treatment area allowing the entire area to be flooded with the oxidizing agent and the hydraulic head of the solution to drive it into the subsurface in much the same way as the COC were introduced into the area during the derailment. A one-time application of the chemical oxidant was completed and is evaluated in Section 7.4.

For the ERD area south of the track, two 3-foot wide and 3-foot deep trenches extending over the 20-foot length of the test area were emplaced. These trenches were filled with gravel and a berm was constructed around the perimeter. The high permeability of the trenches allowed delivery of the ERD carbon source into the subsurface. Four quarterly applications of ERD organic carbon solution were planned; however, after two sampling events the COC evaluated were not detected and, therefore, further applications were discontinued.

A thin cap system would also be designed and implemented as part of this scenario. This cap would cover the embankment up to and under the rails themselves. The main purpose of such a cap system would be to prevent precipitation from entering the vadose zone under the railbed and embankment area. This would encapsulate impacted subsurface soil and mitigate the mobility of contaminants. Such a thin cap system could consist of an applied or sprayed on low-permeability barrier such as Gunite or asphalt or a GCL or GundSeal GCL. Unlike a multi-layer, engineered cap, this cap would utilize materials that could be designed to allow relatively easy, cost-effective installation.

8.3.3.2 Assessment

In order to evaluate the efficacy of the two technologies, a baseline sampling event was performed with soil borings collected in the treatment areas using the direct push method. Vertical samples were analyzed based upon previous knowledge of the vertical distribution of the COC with up to four discrete samples per boring. Performance monitoring will be performed quarterly for up to 1 year in the same manner to evaluate the effect of the technology on the COC. In addition, more frequent soil and groundwater sampling in the ERD test area will be performed to evaluate if more or less frequent application of organic carbon solution is needed.

This alternative is readily implemented and effective for eliminating most of the COC. As long as the thin cap remains intact, the remaining COC should be isolated and relatively immobile. The thin cap will need to be replaced at regular intervals of approximately every 10 years.

8.3.3.3 Time to Achieve Compliance

Assuming 28 working days for contracting and mobilization, 30 working days to construct access to the Site from the north side, 20 working days to install the trenches, approximately 1 year for the ERD , plus 16 working days to apply the Gunite or equivalent barrier and 10 working days for Site restoration and demobilization, the total time to achieve compliance is estimated at 460 working days or 667 calendar days.

8.3.4 Alternative 4A - Removal, Capping, and Treatment/Disposal

8.3.4.1 Description of Application

In this alternative, all impacted soils in both AOI, but not under the railbed, will be addressed by removal. Prior to the removal operation, additional borings will be placed in the AOI by means of a Geoprobe® device as needed to define the area of impact more precisely horizontally and vertically. Because of a concern over the stability of the excavation walls it will be necessary to sheet pile the excavation, along the lake, tributary, and railbed. This will also limit/control the inflow of groundwater and surface water. Schematics of the conceptual plan are given on Figures 23 and 24.

Excavation would most likely be accomplished with a long arm backhoe or trackhoe from areas just behind the sheet piled area. Impacted soil will be removed as it is

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excavated, due to limitations on the working area. The excavation will be backfilled with clean soil.

A mobile laboratory may be used to provide rapid determination regarding adequate removal. The use of a mobile laboratory will also allow analysis of significantly more samples during the excavation operations. Backfilling would be based upon analytical results reported from this operation. Waste soils will be sampled prior to excavation and characterized for off-site disposal in accordance with applicable regulations. Storm water that accumulates in the excavations or in the holding cells will be pumped into a fractionation tank, characterized, and sent off site for disposal.

The COC for the track area have been identified as: 1,2-dichloropropane, dicyclopentadiene, phenol, acrylic acid, disodium iminodiacetate, toluene diisocyanate, and 2,4-toluenediamine. The compound toluene diisocyanate and its breakdown product 2,4-toluenediamine (U223 and U221, respectively) require treatment by combustion to meet the Land Disposal Restrictions (LDR). Soils from areas where toluene diisocyanate/2,4-toluenediamine have been identified will be excavated until these constituents are not detectable and sent off site for incineration. Acrylic acid (U008) likewise is listed as requiring combustion; however, a site-specific variance has been requested from LDEQ to allow soils below the acrylic acid MO-1 cleanup level of 115 mg/kg to remain on site. Soils impacted in excess of this concentration will be sent off site for disposal at an appropriately permitted landfill in accordance with the site-specific variance. In some instances, based upon a phenol concentration in excess of 62 mg/kg, or a 1,2-dichloropropane concentration in excess of 180 mg/kg, the soils may require biotreatment prior to land disposal. Soils impacted with phenol or 1,2-dichloropropane below these concentrations will be directed to appropriate land disposal based upon the Alternative LDR Treatment Standard for contaminated soils.

Confirmation soil samples will be collected in accordance with RECAP to demonstrate that the cleanup levels have been achieved. The excavations will then be backfilled with clean fill and compacted to standard specifications to provide sufficient lateral strength to support the embankment and railbed. The estimated volume that would be removed for this scenario is 61,000 (loose) cy.

The majority of the impacts in the area south of the railbed and north of the lake were removed during the Site cleanup; however, subsequent analysis indicates that some impacts remain under the clean fill brought into the Site, and some of this fill may have been subsequently impacted by constituents in the adjacent soil under the embankment. Impacted soils between the railbed and the lake present environmental and safety

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challenges due to the hydraulic head from the proximity of the lake. Impacted soils north of the railbed present a challenge due to the proximity of the tributary.

It is believed that the sheet piling approach will be adequate for structural and hydraulic containment but if detailed analyses do not bear this out, it is proposed that the soil be removed by means of large-diameter augers, thus eliminating the need for sheet piles. Under this contingency scenario, an interlocking grid of large-diameter (approximately 3-foot) drill shafts will be placed throughout this area. The drill shafts will penetrate clean fill, as defined by the existing and planned borings, which will be removed and stockpiled for future use. The impacted soils will then be removed to pre-planned depths, based upon the boring data, and the soil stockpiled in a similar manner as described above. After each hole reaches the pre-planned depth, the large diameter drill shaft will be withdrawn and the hole backfilled with a flowable fill. The flowable fill will be composed of a mixture of clean sand, Portland cement, and fly ash, or equivalent, that will set up as a solid column, yet be sufficiently friable that the overlapping drill shafts will be able to remove some of the backfill material to minimize the volume of natural material left behind.

The COC in the area south of the railbed are primarily 1,2-dichloropropane and dicyclopentadiene, with the most critical compound (deepest penetration, lowest RS concentration) being 1,2-dichloropropane. The clean up levels utilized for this area, because it extends off UPRR right of way, will be the MO-2 non-industrial concentrations calculated for the site-specific constituents and listed in Table 8. Based upon existing data, it is not anticipated that acrylic acid or toluene diisocyanate/ 2,4-toluenediamine are located in this area, therefore all soil removed for disposal will be sent for direct landfilling at an appropriately permitted landfill. In some instances, based upon a phenol concentration in excess of 62 mg/kg, or a 1,2-dichloropropane concentration in excess of 180 mg/kg, the soils may require biotreatment prior to disposal.

A thin cap system would also be designed and implemented as part of this scenario. This cap would cover the embankment up to and under the rails themselves. The main purpose of such a cap system would be to prevent precipitation from entering the vadose zone under the railbed and embankment area. This would encapsulate impacted subsurface soil and mitigate the mobility of contaminants. Such a thin cap system could consist of an applied or sprayed on low-permeability barrier such as Gunite or asphalt or a GCL or GundSeal GCL. Unlike a multi-layer, engineered cap, this cap would utilize materials that could be designed to allow relatively easy, cost-effective installation.

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8.3.4.2 Assessment

Although removal of impacted soil using excavation techniques is conceptually straightforward, there are many logistical challenges with this technology in this particular setting. These include accessibility for large earth moving equipment, emissions and odor control, the volume of trucks utilizing city streets, and releases to the environment. In addition, even with sheet piling, there are no assurances that the Eunice City Lake dam will remain stable. The thin cap will need to be replaced at regular intervals of approximately every 10 years. Therefore, the implementability of this technology is judged to be high. Because there is limited space available adjacent to the tracks, the soil removed will not be able to be stockpiled, and will need to go directly into trucks. The cost is estimated to be very high, in large part due to treatment and disposal costs.

8.3.4.3 Time to Achieve Compliance

Assuming 28 work days for contracting and mobilization, 30 days to construct access to the Site from the north side, 32 days to drive sheet piling, 15 additional days to collect samples to delineate areas that require incineration versus those that can be landfilled and provide analytical results, then excavate approximately 61,000 (loose) cy of impacted soil and transport off site using approximately 3,813 truck loads at 24 trucks per day = 159 days, for a subtotal of 264 working days. This timing assumes several activities will be completed at the same time, such as driving sheet piling on the north side. Confirmation sampling is estimated to require 21 days and backfilling of the excavations is estimated at 1,500 cy per day from an adjacent borrow pit, or 53 working days. More time will be required if the material needs to be brought in from off-site sources. Site restoration of the right of way, and application of the Gunite or equivalent cap is estimated to require 24 working days. All totaled, the time to reach the remedial standards with this alternative is estimated to require 362 working days or 525 calendar days.

8.3.5 Alternative 4B - Removal and Thermal Treatment

8.3.5.1 Description of Application

The removal part of this alternative is exactly the same as for Alternative 4A. The difference is that the soil under the railbed and embankment would be thermally treated in situ to an estimated depth of approximately 42 ft bls. The most feasible application method for this treatment is a steam distillation approach that would involve installation of numerous "heater wells" to the required depth, heating soil and

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groundwater to the appropriate temperature, and removing any VOCs that are vaporized by means of installed vapor removal points. The heat would efficiently raise temperatures to required levels, boil off part of the pore water, and simultaneously evacuate any VOCs that are not destroyed. Bench scale testing would be necessary to demonstrate complete treatment capability and also soil stability.

A full-scale application would require the use of one or more large capacity generators to create the electricity to drive the heater wells. The time for application would be an estimated 1 to 6 months.

Given the constituents at the Eunice site, it would not likely be necessary to boil off all the water. The technology can be employed to simply raise the soil temperature within most of the treatment volume to the boiling point of water, generating steam in situ. This results in steam distillation of the contaminants, similar to steam flooding or electrical resistance heating. This allows vapors to be drawn into the hot regions in close proximity to heater-vacuum wells, and the enhancement of gas permeability and vapor capture that occurs in such regions. The result is a significant reduction in risk of mobilizing contaminants outside of the treatment zone. This non-desiccation type of thermal treatment can be accomplished with much more widely spaced heaters and simpler off-gas treatment equipment.

In this scenario, the estimated volume of soil that would require thermal treatment is 16,500 cy (in place). Figures 25 and 26 provide schematics for this alternative.

8.3.5.2 Assessment

The assessment of the excavation part of this scenario is the same as for Alternative 4A. Although the concept is relatively straightforward there are many logistical challenges. These include accessibility for large earth moving equipment, emissions and odor control, the volume of trucks utilizing city streets, and potential releases to the environment.

The addition of thermal treatment adds an additional level of complexity. Assuming that bench scale testing indicates that the thermal approach has a good probability of destruction of contaminants to below RECAP levels and that soil stability would not be adversely affected, this technology could be a very effective way to treat soil below the railbed and embankment. Again, the advantage of this system is that it can be employed without interrupting rail service.

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The cost for the combined technologies is estimated to be very high, in large part due to the thermal treatment and soil disposal costs.

8.3.5.3 *Time to Achieve Compliance*

The time for the removal and backfilling portion of this alternative is the same as above, 264 working days. Assuming that the thermal treatment takes the full 6 months to complete would equal 126 working days. Site restoration activities are estimated to require 25 working days. The time to meet the remediation standards utilizing this alternative would be 415 working days or 602 calendar days.

8.3.6 Alternative 4C - Removal and Treatment/Disposal

8.3.6.1 *Description of Application*

The removal part of this alternative is similar to Alternatives 4A and 4B. The difference is that all of the soil under the embankment would be removed and transported off site for landfilling, treatment, and disposal. Of course, this would require that rail service be interrupted while the 16,500 cy of soil under the railbed is removed. This is estimated to require 54 working days while the excavation and backfilling activities are occurring (utilizing the rates described in 4A). The estimated total volume of removed and treated soil is 77,500 (loose) cy. Schematic representations of where the removal would take place are given on Figures 27 and 28.

8.3.6.2 *Assessment*

As with Alternatives 4A and 4B, although removal of impacted soil using excavation techniques is conceptually straightforward, there are many logistical challenges with this technology in this particular setting. These include access issues for large earth moving equipment, slope stability, hydraulic control of nearby lake and tributary waters, emissions and odor control, transportation of the impacted soil through city streets and releases to the environment. Therefore, the implementability of this technology is judged to be moderate to difficult. The cost is estimated to be very high, in large part due to treatment and disposal costs.

8.3.6.3 *Time to Achieve Compliance*

Assuming 28 work days for contracting and mobilization, 30 days to construct access to the Site from the north side, 32 days to drive sheet piling on the south side, 15 additional days to collect samples to delineate areas that require incineration versus

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those that can be landfilled and provide analytical results, then excavate approximately 77,500 (loose) cy of impacted soil and transport off site using approximately 4,843 truck loads at 24 trucks per day = 202 days, for a subtotal of 306 working days. This timing assumes several activities will be completed at the same time, such as driving sheet piling on the north side. Confirmation sampling is estimated to require 21 days and backfilling of the excavations is estimated at 1,500 cy per day, from an adjacent borrow pit, or 51 working days. More time will be required if the material needs to be brought in from off-site sources. Site restoration of the right of way is estimated to require 5 working days. All totaled, the time to reach the remedial standards with this alternative is estimated to require 384 working days or 557 calendar days.

8.3.7 Alternative 5 - In Situ Thermal Treatment

8.3.7.1 Description of Application

This alternative is similar to Alternative 4B except that the in situ thermal treatment would be applied to virtually the entire site and no removal would be performed. An estimated in place soil volume of 59,615 cy would be subjected to heating using the heater well/vapor control well technology described previously. Figures 29 and 30 provide schematics for this alternative.

8.3.7.2 Assessment

The potential advantages of this alternative are that rail service would not have to be interrupted and many concerns associated with removal of impacted soil would be mitigated. Also, if the thermal approach proves effective, it could treat COC to RS everywhere. These advantages could potentially outweigh the very high cost and logistical challenges of large-scale thermal treatment.

8.3.7.3 Time to Achieve Compliance

Although the volume to be treated (approximately 59,615 in place cy) is 3.6 times the amount of soil to be treated in Alternative 4B, the treatment time is not totally linear based upon the volume. It is estimated that the entire area can be treated to meet the remedial standards in 1.5 to 2 years, or approximately 505 working days or 732 calendar days.

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8.3.8 Alternative 6A - Excavation and ERD Combination

8.3.8.1 Description of Application

This alternative utilizes a combination of technologies. Chemical oxidation of the north side of the right of way took place during the technology evaluation and appears to have effectively reduced the COC amenable to that treatment. ERD will be used to address 1,2-dichloropropane and the remaining COC, in conjunction with removal and disposal of a portion of the railbed. In this alternative, the replacement of the pre-derailment bridge length would be enhanced by the removal of railbed material and any impacted native soil beneath the original bridge footprint. This alternative has the advantage of restoring the pre-derailment bridge span over the tributary, utilizing drilled shaft piers The unexcavated portion of the railbed area will be confined within sheet piles, and ERD solution will be utilized to treat the COC impacts. The same delivery mechanism (trenches and cell areas) utilized for the evaluation on the north side of the embankment will be utilized for the application of ERD to address the 1,2-dichloropropane . Deeper areas of impact will be addressed through deeper trenches excavated by a long arm trackhoe, with sheet pile, as needed, to shore up the sides.

Confirmation sampling to confirm that the RS have been achieved will be performed with a Geoprobe® sampling device.

8.3.8.2 Assessment

The advantages of this alternative are that much of the impact under the railbed is addressed through excavation, and the impacts within the right of way and under the remaining portion of the railbed are addressed in situ. Excavated material will be transported through residential neighborhoods and backfill material brought into the Site, depending upon available borrow material. The pre-derailment drainage through the track area will be restored. Implementing this alternative will take advantage of the need for heavy equipment necessary to complete the bridge replacement; therefore, it is implementable. The cost for the construction of this combination of technologies is moderate, although the impact of closing the rail line is high. Figures 31 and 32 provide the schematics for this alternative.

The disadvantages of this alternative include the following: the large volume of soil to be excavated prohibits treatment on site due to limited land area available for a treatment cell, a large volume of trucks will be required to access residential streets to remove the impacted soil, the length of time required for excavating both the embankment and the ground beneath the embankment, and the threat to the stability of the Eunice City Lake dam. Assuming that the excavation below grade would remain stable on a 1:1 slope, the excavation of all impacted soil beneath the railbed footprint (shown on Figure 31) would require removal of approximately 22,000 cy. This volume of material would be sent off site for disposal. The below grade excavation, coupled with the time necessary to backfill with compacted soil, is estimated to require 68 working days while the excavation and backfilling activities are occurring (utilizing the rates described in 4A) plus an additional 3 days to construct the bridge, assuming the drilled shafts and pile caps are emplaced before excavation begins for a total disruption of service of 71 working days. The disruption of rail service is a critical factor. In addition, even with sheet piling protecting the excavation, the stability of the Eunice City Lake dam could not be assured given the width and depth of the excavation necessary to remove all the impacts beneath the embankment.

8.3.8.3 *Time to Achieve Compliance*

Assuming 28 working days for contracting and mobilization, 30 working days to construct access to the site from the north side, 10 working days to drive sheet piling, 15 working days to collect samples to delineate areas that require incineration versus those that can be landfilled and provide analytical results, 68 working days to excavate and backfill under the bridge area, and 3 working days to construct the bridge, assuming the drilled shafts and pile caps are emplaced before excavation begins, the accelerated construction schedule will take 154 working days. At that point the trenches can be excavated (21 working days) and the ERD can be accomplished over approximately 1 year , for a total of 619 calendar days to achieve compliance.

8.3.8 Alternative 6B - Limited Embankment Excavation and ERD Combination

8.3.8.1 *Description of Application*

This alternative is similar to Alternative 6A except that, in this alternative, the replacement bridge would be approximately 228 feet long (the old bridge was 189 feet) and cover most of the area LDEQ requested be excavated. Under this alternative the aboveground portion of the embankment would be excavated, both under the new bridge and, to the limits of the area originally requested by LDEQ, east of the bridge abutment. The pile caps would be placed on drilled shafts, or other acceptable support, prior to the track being taken out of service. The below grade area beneath the bridge will be treated in situ after the construction is completed. Likewise, the below grade area under the embankment east of the bridge abutment will be treated after construction by means of trenches and pipes emplaced in this area after the

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embankment is removed and before new ballast is put in place. This alternative has the advantages of creating a larger drainage opening, eliminating the trucking of large volumes of soil through residential areas, and treating a smaller volume of impacted material in a biopile beside the track. Because the COC impacting this earthen material is primarily 1,2-dichloropropane, the excavated material would be treated by ERD. The track will be shut down for a shorter period of time (approximately 6 days) than Alternative 6A while the railbed is excavated and the new bridge is constructed. The excavated materials will be treated in a biopile north of the track, while all below grade impacts will be treated in situ. The remaining areas of impact will be addressed through trenches excavated by a long arm trackhoe, with sheet pile, as needed, to shore up the sides.

Confirmation sampling to confirm that the RS have been achieved will be performed with a Geoprobe® sampling device.

8.3.8.2 Assessment

The advantages of this alternative are that the impacts under the railbed are addressed, as are impacts within the right of way. No impacted material will be removed from the Site through residential neighborhoods. In addition, the drainage through the track area will be restored with a greater opening through the track, while disruption of rail service will be minimized. By excavating a smaller volume of impacted soil than would be required under Alternative 6A (approximately 6,500 cy versus approximately 22,000 cy), the use of a biopile is possible. By not excavating below grade, except for the trenches required for treatment, sheet piling is not required and the potential threat to the Eunice City Lake dam is eliminated. This alternative is readily implemented. The cost for this combination of technologies is moderate. Figures 33 and 34 provide the schematics for this alternative.

8.3.8.3 Time to Achieve Compliance

Assuming 28 working days for contracting and mobilization, 30 working days to construct access to the Site from the north side, 15 working days to construct the treatment cell, 14 working days to excavate the embankment under the bridge area , and 6 working days to construct the bridge after the piles and caps are in place, the accelerated construction schedule will take 93 working days. At that point the trenches can be excavated (21 working days) and the ERD can be accomplished over approximately 1 year, for a total of 530 calendar days to achieve compliance.

8.3.9 Alternative 6C – Embankment Excavation and ERD Combination

8.3.9.1 Description of Application

This alternative is similar to Alternative 6B except that, in this alternative, the replacement bridge would be approximately 326 feet long (instead of 285 feet in Alternative 6B) and cover almost all of the impacted area under the embankment. The pile caps will be supported by four-pile clusters on each end that are driven inside a 9-foot diameter casing. The casings will be driven to below the depth of impact, and the impacted soil will be removed prior to the piles being driven. The below grade area beneath the bridge will be treated in situ after the construction is completed. This alternative has the advantages of creating a much larger drainage opening, eliminating the trucking of large volumes of soil through residential areas, and treating a relatively small volume of impacted material in a biopile beside the track. Because the COC impacting this earthen material is primarily 1,2-dichloropropane, the excavated material would be treated by ERD. The track will be shut down for a short period of time (approximately 3 days), assuming that the piles and caps are in place prior to the track being shut down. The excavated materials will be treated in a biopile north of the track, while all below grade impacts will be treated in situ. The remaining areas of impact will be addressed through trenches excavated by a long arm trackhoe, with sheet pile, as needed, to shore up the sides.

Confirmation sampling to confirm that the RS have been achieved will be performed with a Geoprobe® sampling device.

8.3.8.2 Assessment

The advantages of this alternative are that all the impacts under the railbed are addressed, as are impacts within the right of way. No impacted material will be removed from the Site through residential neighborhoods. In addition, the drainage through the track area will be improved with an even greater opening through the track, while disruption of rail service will be minimized. By treating a smaller volume of impacted soil than would be required under Alternative 6A (approximately 8,500 cy versus approximately 22,000 cy), the use of a biopile is possible. By not excavating below grade, except for the trenches required for treatment, the need for sheet piling and the potential threat to the Eunice City Lake dam is eliminated. This alternative is readily implemented. The cost for this combination of technologies is moderate. Figures 34 and 35 provide the schematics for this alternative.

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8.3.8.3 Time to Achieve Compliance

Assuming 28 working days for contracting and mobilization, 30 working days to construct access to the Site from the north side, 15 working days to construct the treatment cell, 14 working days to excavate the embankment under the bridge area, and 3 days to construct the bridge after the piles and caps are in place, the accelerated construction schedule will take 90 working days. At that point the trenches can be excavated (21 working days) and the ERD can be accomplished over approximately 1 year for a total of 526 calendar days to achieve compliance.

8.4 Comparative Analysis of Remedial Alternatives

In Section 8.3, each of the remedial alternatives for the Site was evaluated on an individual basis. This section provides a comparative analysis of the expected performance of each alternative relative to the other alternatives to identify their respective advantages and disadvantages. The comparative analysis is summarized in Table 22.

8.4.1 Ability to Achieve RECAP Standards

Alternative 1 does not achieve RS. Alternatives 2 through 4 address each of the RAOs identified for the Site and offer some potential to partially or completely achieve RS. The primary difference is that Alternative 2 is primarily a containment technology (although some vapor extraction/treatment would occur) and would not provide treatment per se. Alternative 3 is an in situ treatment technology that is potentially capable of meeting RS but the means of application must be successfully tested to confirm this. Alternative 4A would achieve RS north and south of the embankment but would leave the soil below the railbed and embankment in a "contained" condition. Alternatives 4B and 4C involve technologies that should be able to achieve RS if all impacted soil can be removed and/or thermally treated completely. Alternative 5 has the potential to achieve RS everywhere if the technology proves effective for this application. Based upon the technology evaluation performed at the site, Alternatives 6A, 6B, and 6C have the potential to achieve RS everywhere, including the railbed and the embankment.

8.4.2 Long-Term Effectiveness and Permanence

Alternative 1 is not an effective long-term technology. Alternative 2 provides long-term effectiveness because the stabilized material should stay "contained" essentially indefinitely. However, the capped portion of the area (the railbed and embankment) would need to be maintained on a regular basis. Alternative 3 offers a complete and permanent means of in situ contaminant reduction or destruction if the delivery techniques prove to be effective everywhere. Alternatives 4A, 4B, and 4C should be effective over the long term although Alternative 4A is somewhat less permanent because soil under the railbed and embankment would be capped, not treated/removed. Alternative 5 has the potential to achieve permanence if the technology proves effective for the Site conditions. Alternatives 6A, 6B, and 6C offer a complete and permanent means of in situ contaminant reduction or destruction.

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8.4.3 Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternative 1 would not result in any reduction in the nature of the contaminants. Alternative 2 would substantially but not completely result in a reduction in the amount of contaminant mass and its toxicity due to the micro-encapsulation, treatment, and containment of constituents. It would also result in a major if not complete reduction in the mobility of contaminants. Alternative 3 would potentially eliminate the toxicity, mobility, and volume of contaminants if the delivery techniques utilized prove to be effective. Alternatives 4A, 4B, and 4C should also be very effective in reductions in the same criteria, although Alternative 4A would not result in destruction of COC toxicity and mass in soil under the railbed and embankment. Alternative 5 would achieve complete reduction in toxicity, mobility, and volume if thermal treatment proves effective for this Site. Alternatives 6A, 6B, and 6C would eliminate the toxicity, mobility, and volume of contaminants.

8.4.4 Short-Term Effectiveness

Alternative 1 is not effective in the short term. Alternative 2 would achieve effectiveness immediately after completion of stabilization and the installation of the thin cap system. Alternative 3 would also achieve short-term effectiveness after completion of the injections, assuming that the delivery techniques are capable of reaching all of the COC. Alternatives 4A, 4B, and 4C should also become quite effective immediately after completion of thin-wall capping, excavation, and/or the application of thermal treatment, respectively. Thermal treatment in Alternative 5 would be effective within a short period of time after target temperatures are reached within the ground (again, assuming the effectiveness of the technology for Site conditions). Alternatives 6A, 6B, and 6C would also achieve short-term effectiveness after all the site areas are addressed. They would have the added advantages of restoring or improving the pre-derailment drainage profile of the tributary. Alternative

6A would disrupt the rail service, while Alternatives 6B and 6C would minimize the disruption of critical rail service to the state. Figure 36 depicts the depths and areas to be excavated under Alternatives 6 A, B and C.

8.4.5 Implementability

Alternative 1 is readily implementable but not effective. Alternatives 2, 3, 5, 6A, 6B, and 6C are implementable but require considerable care and expertise in the design, planning, and implementation phases. Alternatives 4A and 4B present increased difficulty in implementation because, in all scenarios, material must be removed from the ground, managed on site, and transported off site, presenting logistical challenges and potential threats to Eunice City Lake dam. There is also an increased concern for the health and safety of workers, for the ambient environment, and to the health of neighbors. Alternative 4C provides the same concerns plus the added challenge of having to interrupt rail service for a significant period of time.

8.4.6 Relative Cost

Alternative 1 is low cost but not effective. The estimated cost for Alternative 2 is **$4,967,053** but low in O&M and does not require the interruption of rail service. The estimated cost for Alternative 3 is **$3,257,323** if the technology proves to be effective. It also would be low cost for O&M and does not require the interruption of rail service. Alternatives 4A, 4B, and 4C are all more costly remedial alternatives, in part because they all require disposal of impacted soil. Estimated costs for these alternatives are **$9,104,648, $13,723,895, and $9,751,943**, respectively. The cost for Alternative 4B is very high because of the in situ thermal treatment; however, it potentially avoids interrupting rail service. Alternative 4C is high because it involves the greatest removal and disposal volume and it requires that rail operations be interrupted during reconstruction of the railbed and embankment. Again, all of the options under Alternative 4 assume non-hazardous waste disposal. Hazardous disposal of part or all of the removed soil would dramatically raise these costs. The estimated cost for Alternative 5 is **$16,904,500**. Although the highest of all costs, this alternative potentially involves neither disposal nor the temporary interruption of rail service. The estimated cost for Alternative 6A is **$6,124,830**, for Alternative 6B is **$3,695,150**, and for Alternative 6C is **$3,727,050.** This does not include the cost of the bridge replacement because that is being done with engineering funds. Estimated costs for the various alternatives are given in Table 23. These costs are approximate costs based on experience, recent prices from vendors, and standard engineering references. In general, the accuracy of costs are within +/-30 percent of the probable expenditures.

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8.4.7 Compliance with ARARs

Each of the alternatives should be capable of attaining ARAR compliance, primarily RS, with the exception of Alternative 1. The RGs as established in this report are the MO-2 limiting RS.

9.0 Selection of Remedy

Based upon the analysis of the remedial alternatives, the best balance between all the factors considered is to utilize Alternative 6C. This alternative potentially provides the following attributes:

- Permanent destruction of COC in all impacted soils;
- Improvement of the pre-derailment drainage within the tributary;
- Minimal impact on critical rail service needed for post-hurricane relief rebuilding efforts;
- Low impact on surrounding community;
- Readily implementable; and
- Moderate capital cost and low O&M costs.

Additionally, this alternative requires the least amount of large equipment utilizing residential streets.

10.0 Contingency Plan

Post- corrective action sampling for the impacted soils will be performed at the end of the approved corrective action period. The number of data points to be collected will be determined utilizing the methods specified in SW-846 *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods.* If the sampling indicates that the COC have not been reduced to below the remedial standards, in accordance with RECAP, Section 2.19, Union Pacific will excavate, properly dispose of, and replace the soil impacted above the remedial standards by one of the excavation techniques evaluated above. The technique utilized for excavation will be based upon the most efficient method available to remove the affected area(s).

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